DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 277

# GROUND WATER

IN

# JUAB, MILLARD, AND IRON COUNTIES UTAH

BY

OSCAR E. MEINZER

IN COOPERATION WITH THE STATE OF UTAH
CALEB TANNER, STATE ENGINEER

WASHINGTON
GOVERNMENT PRINTING OFFICE
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# ILLUSTRATIONS.

# GROUND WATER IN JUAB, MILLARD, AND IRON COUNTIES, UTAH.

By Oscar E. Meinzer.

## INTRODUCTION.

*Location and extent of area.*—Juab, Millard, and Iron counties lie in western Utah, and, with the exception of a small part of Iron County, are entirely within the Great Basin. (See fig. 1.) They comprise about 13,650 square miles, of which approximately 3,500 belong to Juab, 6,775 to Millard, and 3,375 to Iron County. Beaver County, which lies between Millard and Iron counties, is not discussed in this paper because its water resources have been described by W. T. Lee, of the United States Geological Survey, in Water-Supply Paper 217.

*Purpose of investigation.*—The investigation was begun in the summer of 1908, under cooperative agreement between the Director of the United States Geological Survey and Caleb Tanner, State engineer of Utah, the object of the work being to obtain and disseminate information which should lead to a greater utilization of the ground-water supplies.

The agricultural development of an arid section, such as this, is primarily dependent on the amount of water available. Large tracts of fertile soil remain idle year after year for lack of water for irrigation, while much water that falls as rain and snow sinks into the ground, saturates the porous materials underlying the valleys and deserts, and eventually reappears at the surface in low alkali flats, where it is dissipated by evaporation without producing useful vegetation. If the water thus lost can be applied to fertile soil it will substantially increase the agricultural yield of the region.

An urgent demand for information in regard to ground-water prospects has been created in recent years by the adoption of dry farming methods in localities where water is not readily obtained. The water required for culinary purposes and for supplying the horses and traction engines used in tilling the soil on some of the dry farms is at present hauled long distances.

In most of the arid parts of this region watering places of any sort are so scarce that certain sections are accessible for grazing only

in the winter when sheep will depend on snow for their water supply. In some of these sections an intelligent search would probably discover ground-water supplies which would increase greatly the value of the range.

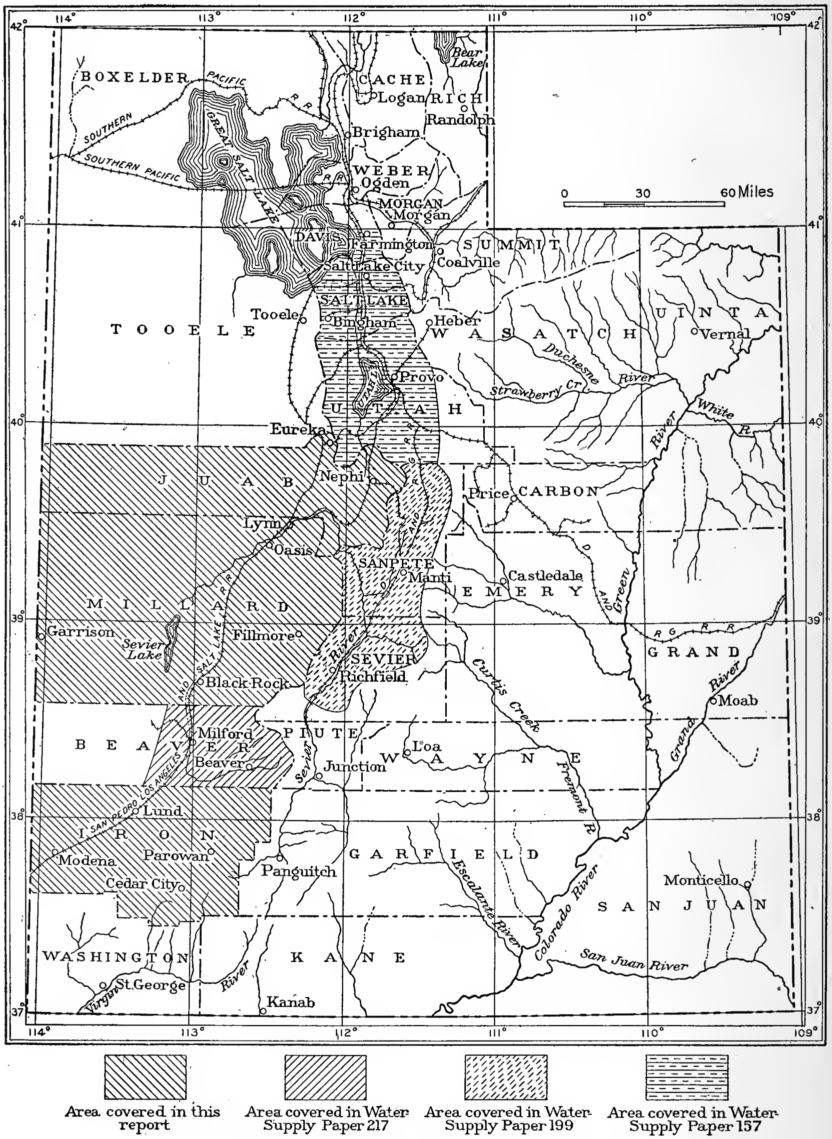


FIGURE 1.—Map of Utah, showing areas investigated.

*Acknowledgments.*—Valuable information was furnished by the San Pedro, Los Angeles & Salt Lake Railroad Co. in regard to deep railway wells; and four samples of water were analyzed by the State

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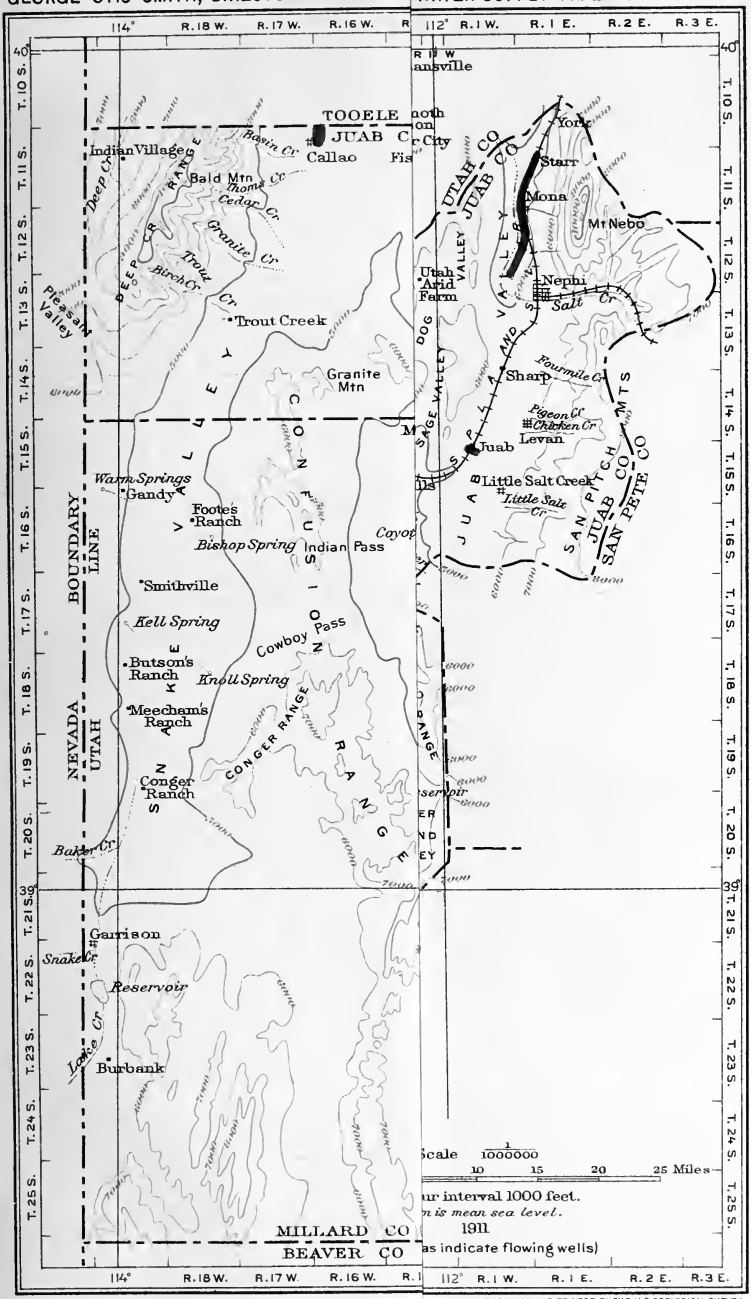
WATER-SUPPLY PAPER 277 PLATE I

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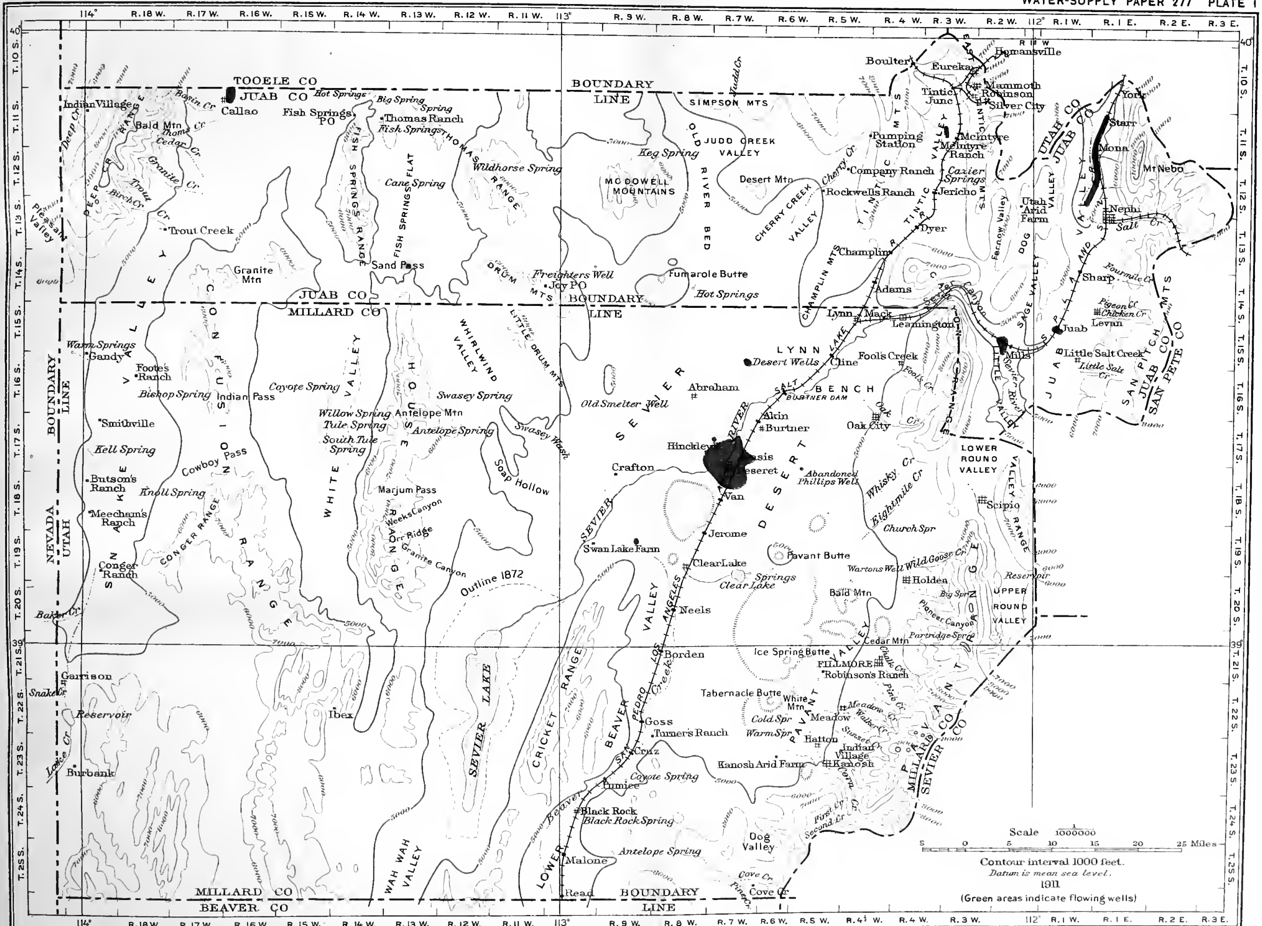
TOPOGRAPHIC MA ING WELLS




TOPOGRAPHIC MAP OF JUAB AND MILLARD COUNTIES, UTAH, SHOWING AREAS OF FLOWING WELLS

Agricultural College at Logan, Utah. Thanks are also due to the inhabitants of the region for their hospitality and generous assistance.

## PHYSIOGRAPHY.

### UNITS OF DISCUSSION.

In dividing this region into units for convenience of discussion it has been found necessary to draw some rather arbitrary boundaries, to use names that have hitherto been known only locally, and to more definitely restrict recognized names than has heretofore been done.

The term "Sevier Desert" has long been used to designate a large and indefinitely bounded region; as used in this paper it refers to an area that is bounded on the north by the Juab-Millard County line, on the east by the Canyon Range, on the south by a line passing through Pavant Butte (Sugar Loaf Mountain) and the north end of the Cricket Mountains (Beaver Range), and on the west by the Little Drum Mountains, Swasey Wash, and the Long Ridge. The adjacent region north of the county line is here called the "Cherry Creek and River Bed region." The term "Pavant Valley," which in the past has been used vaguely, is here applied to the lowland tract which extends from Holden to Kanosh and is bounded on the east by the Pavant Range and on the west by Pavant Butte and the lava fields that extend southward from it. The name "Lower Beaver Valley" is used for the valley through which the channel of Beaver Creek passes, from Beaver County to Sevier Desert.

To that part of the valley of Sevier River which lies in Juab County between the Canyon Range and the northward extension of the Valley Range the name "Little Valley" is locally applied, and this name is used in this paper. For the tract extending from Sevier River to the "Dog Valley" in Juab County the name "Sage Valley" is used.

The term "Round Valley" has been applied to the upper valley of Ivie Creek, which contains the reservoir, and also to the lower valley, in which Scipio is situated. To avoid ambiguity, the expressions "Upper Round Valley" and "Lower Round Valley" are used in this paper.

### PROVINCES.

Southwestern Utah belongs to two major physiographic provinces—the Plateau province and the Basin province. The former consists of nearly horizontal rock strata that have been lifted to a high altitude and deeply dissected by running water; the latter consists of a desert plain, several thousand feet lower, interrupted by more or less parallel and isolated mountain ranges which are as a

rule composed of rock strata that have been faulted and tilted. The boundary between these two provinces is an escarpment or series of escarpments, which, viewed from the Basin province, has the aspect of a lofty mountain range. The three counties here considered lie chiefly in the Basin province, and their eastern boundaries are in general formed by the escarpment of the Plateau province.

### STREAM TOPOGRAPHY.

Superimposed on the grand features produced by the diastrophic forces that have lifted the plateaus and thrust up the Basin ranges are the features produced by running water. The temporary and permanent streams of the region are the agents in two complementary processes that give rise to two shaply contrasted types of topography. In their upper courses on the mountains and plateaus these streams have steep gradients and erode vigorously, thus cutting deep canyons and creating intricately carved surfaces; but in their lower courses—the low areas intervening between the mountain ranges—they are more sluggish, and their waters disappear by evaporation and downward percolation, thus depositing the sediments which they wrested from the mountains and building extensive gently sloping and featureless alluvial fans. Adjacent fans merge with each other to form broad, smooth, alluvial slopes that everywhere surround the rugged mountain ranges. The alluvial slopes of neighboring ranges extend toward each other, and the base of one may nearly touch the base of the other. The entire area between two ranges is in this region commonly called a "valley."

If there had been no weathering and no work had been done by the streams, the relief resulting from the deformation of the rocks would be much greater than it is. The plateaus and mountains would be higher; the basins would be lower. Ever since these topographic irregularities came into existence the streams have been at work obliterating them by tearing down the mountains and filling the intervening basins. The extent to which the basins have thus been filled is known definitely at only a few points where wells of unusual depth have been sunk, but in many places this filling is probably very deep.

### LAKE TOPOGRAPHY.

Superimposed on the surface molded by running water are strikingly different features produced by the waters of an ancient lake. Along the shores of this ancient lake were formed cliffs, terraces, beach ridges, bars, spits, and deltas such as exist along the shores of modern lakes. Shore features were formed at every level at which the lake stood for some time, but they are the most prominent at two levels known as the Bonneville and Provo levels. (See p. 18.) They

have a horizontal arrangement which attracts attention by its contrast with the oblique lines produced by stream work.

Since the desiccation of the ancient lake few important topographic changes have taken place. The low areas are still undergoing aggradation rather than degradation, but the upper parts of the alluvial slopes are in some places being subjected to stream erosion.

### WIND TOPOGRAPHY.

Wind work has been most effective in rehandling the sand that was washed by the waves upon the shores of the ancient lake. The storm winds at the time the lake was in existence seem to have been prevailingly from the west, as they are at the present time, and the largest accumulations of sand were consequently made on the eastern shore, where they have given rise to many dunes, especially in the area between Cherry Creek and Holden.

In the White Valley wind erosion has produced a fantastic hummocky topography (see p. 122), and in Snake Valley the wind has helped to build large knolls about some of the principal springs (see pp. 44–45).

### MINOR BASINS.

The Basin province contains a number of distinct and independent drainage systems that are separated from each other by divides formed by rocky ridges or low accumulations of alluvium. If a valley has an abundant water supply it may have an outlet through which its streams discharge either continuously or at times of flood. Thus the north basin of Juab Valley discharges into Utah Valley, which discharges into Great Salt Lake. Thus the south basin of Juab Valley discharges into Little Valley and thence, through Sevier River, into Sevier Lake. Thus, too, at times of high water a part of Rush Lake Valley discharges into Escalante Desert. But where the water supply is meager or other conditions are less favorable, overflow does not take place and the basin has a closed drainage. Such basins are formed, for example, by Parowan Valley, White Valley, and Lower Round Valley.

The outlets of some of the valleys consist of canyons cut through rock walls, as, for example, Sevier Canyon, which leads from Little Valley to Sevier Desert; the canyon of Currant Creek, which forms the outlet of the northern part of Juab Valley; and the canyon of Chicken Creek, which forms the outlet of the southern part of Juab Valley. Some of these canyons do not occur at the lowest parts of the inclosing rim, but have been cut boldly through higher mountainous parts. They appear to be the work of streams which flowed before the rock barriers were thrown up and which persisted in their

courses during the deformation by cutting down their channels as rapidly as the rocks were lifted.

Hieroglyph Canyon, which is cut through the barrier between Parowan and Rush Lake valleys, and the channel that leads from Lower Round Valley to Little Valley were both obviously formed by running water, though they are no longer occupied by streams, even in times of flood. In some of the other outlets the streams are so small and intermittent that they could scarcely have produced the canyons which they occupy. Doubtless when the climate was sufficiently humid to produce the large ancient lake all these gorges were traversed by vigorous streams, but the date of their origin seems to be earlier.

The north basin of Juab Valley, a part of the Old River Bed region, the region north and northwest of the McDowell Mountains, Fish Springs Valley, and a part of Snake Valley belong to the Great Salt Lake drainage basin. The south basin of Juab Valley, Little Valley, Tintic Valley and its mountain borders, a part of Sevier Desert, Lower Beaver Valley, a part of Wah Wah Valley and some of the high area farther west, and the Swasey Wash region belong to the Sevier Lake drainage. White Valley and Round Valley each forms a closed drainage basin; Snake Valley contains several rather distinct drainage basins; and Sevier Desert, though nearly flat, contains several depressions which are more or less independent of each other. Thus the swampy area in the vicinity of the Hot Springs north of Abraham does not normally drain into Sevier Lake, and the same seems to be true of certain ponds and swamps near Pavant Butte, of the swampy tract west of Holden, of Chalk Creek Sink, and of the bottoms farther south.

Parowan Valley, Escalante Desert, and parts of Rush Lake Valley form independent drainage basins, but a part of Rush Lake Valley is more or less tributary to Escalante Desert.

The large number of independent basins is a result of arid conditions. In the dry seasons a drainage system becomes dismembered, the water from different parts terminating in insignificant local depressions; when more humid conditions return, these local depressions quickly fill with water and overflow, thus reuniting the drainage from different parts into a single system. In the past the overflowing and uniting process continued until practically all of this area discharged its waters into the ancient lake, and hence belonged to a single drainage basin. At last the ancient lake itself overflowed (pp. 16–18) and for a time the entire region became tributary to the Pacific Ocean. If humid conditions had continued long enough, the outlet would have been cut so low that the lake would have been drained completely, and by a similar process the minor depressions would also have been drained.

## GEOLOGY.[1]

### FORMATIONS.

The rocks exposed in the large area here considered probably range in age from pre-Cambrian to Recent.

The rocks supposed to be pre-Cambrian consist mainly of granite and are found in only a few localities.

The Paleozoic formations include a great thickness of apparently conformable beds which consist chiefly of quartzites and indurated dark-gray limestones of Cambrian and Carboniferous age. The Basin ranges are composed of these rocks.

Above the quartzites and limestones are several thousand feet of highly colored clastic beds which belong to the Permian series of the Carboniferous, and to the Triassic and Jurassic systems. They are best exposed in the plateau in eastern Iron County, but are not confined to this region. Above the Jurassic is a succession of Upper Cretaceous shales and sandstones, which have a grayish appearance and aggregate several thousand feet in thickness. Like the Jurassic, they are best developed in eastern Iron County, but are also found farther north. Beds of gypsum occur in the Jurassic and coal in the Cretaceous.

At higher horizons are found early Tertiary conglomerates, sandstones, shales, and limestones of nonmarine origin. In Iron County they rest on the Cretaceous beds; but in the Canyon Range, in parts of the Pavant Range, and in the low ridges east of these, sandstones and conglomerates presumably of Tertiary age rest with a pronounced unconformity on Paleozoic quartzites and limestones.

Stream, lake, and wind deposits, consisting of relatively unconsolidated gravel, sand, and clay, occur to great depths beneath the valleys and low desert tracts. These sediments were the last to be deposited and are late Tertiary, Pleistocene, and Recent in age. As there are few outcrops the relative importance of stream and lake sediments is largely a matter of conjecture. At the foot of the lofty mountains and plateaus in the eastern part of this region stream deposits and coarse beach and delta deposits of local origin predominate, but far out in the deserts fine-grained lake sediments are present in large quantities. The smaller Basin ranges furnish only meager amounts of rock waste. In some places, as at the north end of Fish Springs Range, they are partly buried beneath the lake flat and are nearly devoid of alluvial slopes. The Neels and Goss railroad wells, in Lower Beaver Valley, are near the Cricket Mountains, yet they reveal sections consisting almost exclusively of fine sediments.

[1] The brief sketch here given is chiefly summarized from the works of the geologists who have studied the region, especially the Geology of the High Plateaus of Utah, by C. E. Dutton: U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

such as would settle to the bottom of a lake at some distance from the shore from which they are derived. (See pp. 98–100 and Pl. III.)

Volcanic rocks are widely distributed over this region. They are all or nearly all younger than the early Tertiary strata, upon which they rest in many places. They belong chiefly to the later epochs of the Tertiary period, but are in part coeval with the ancient lake and in part still more recent.

### GEOLOGIC HISTORY.

Paleozoic formations containing marine fossils occur generally in this region, and it is therefore certain that during at least a part of the Paleozoic era the region was covered by the sea. Mesozoic and Tertiary formations are strongly developed in the plateaus and in some of the ranges near the Plateau province, but they are absent over most of the Basin province. It has therefore been inferred that most of the Basin province emerged from the sea before the Mesozoic and Tertiary sediments were deposited.

Throughout the Basin province the Paleozoic formations have been faulted and tilted to produce the Basin ranges. It is not known at what time these faulting movements began, but fresh scarps on the alluvial slopes of some of the ranges, as, for example, in the vicinity of Fish Springs,[1] show that they are still in progress.

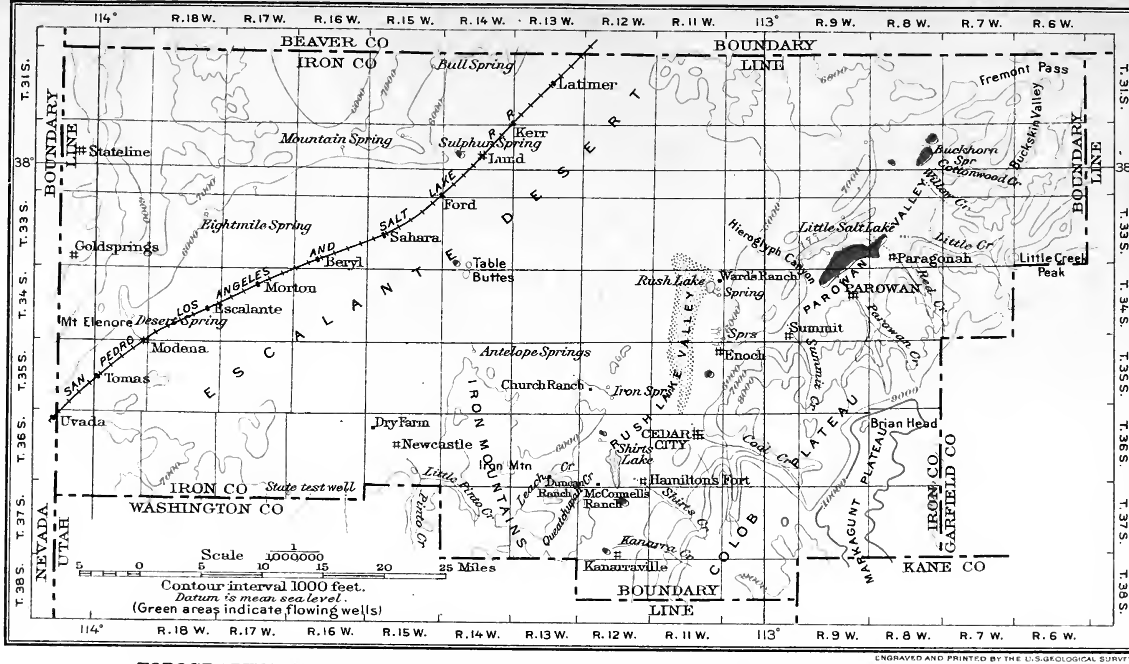
In the Colob Plateau, in eastern Iron County, the great thickness of Permian and Mesozoic strata that intervenes between the earlier Carboniferous and Tertiary rocks indicates sedimentation during much of the interval which they represent, but the fact that in the Canyon Range and adjacent mountains Tertiary deposits rest directly on the eroded and irregular surface of the early Carboniferous or the older Paleozoic rocks indicates that erosion was here taking place during much of the time that sedimentation was in progress in the Colob Plateau region.

After the early Tertiary sediments had been deposited the Plateau province was lifted bodily with reference to the Basin province, thus producing the escarpments that form the boundary between these two provinces. This relation is best shown in Iron County, where the tabular, though greatly dissected, Markagunt and Colob plateaus tower above the basins and low ranges to the west, separated from them by a profound fault and an imposing fault scarp known as the Hurricane Ledge. Farther north the boundary between the two provinces is less definite. The Pavant Range and the mountain mass east of Juab Valley have some of the characteristics of each province.

In the Pleistocene epoch western Utah contained a large lake, which has been fully described by G. K. Gilbert,[2] who named it Lake

[1] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890, p. 353.

[2] Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890. The description of Lake Bonneville in this paper is largely abstracted from Mr. Gilbert's monograph.




TOPOGRAPHIC MAP OF IRON COUNTY, UTAH, SHOWING AREAS OF FLOWING WELLS

1911

Bonneville.[1] At the time of its maximum extent this lake covered an area of 19,750 square miles and was 346 miles long, measured in a straight line, 145 miles wide, and 1,050 feet in maximum depth. Its surface was about 5,200 feet above the present sea level, or about

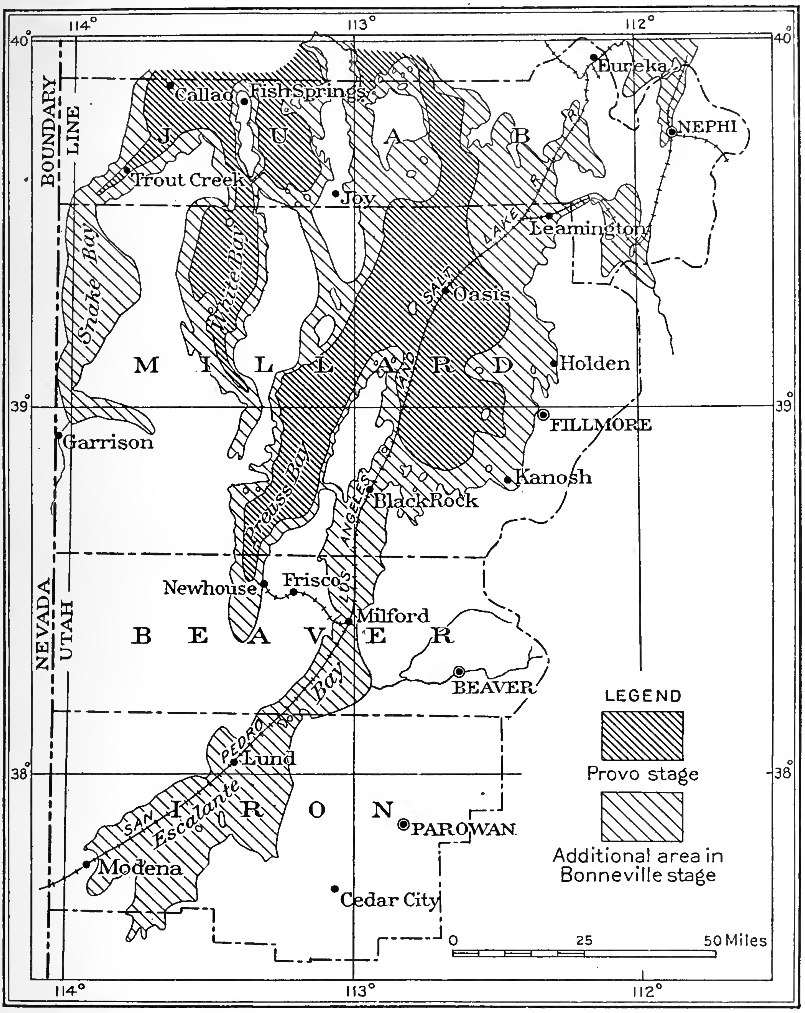



FIGURE 2.—Map of Juab, Millard, Beaver, and Iron counties, Utah, showing areas covered by Lake Bonneville. (After G. K. Gilbert, Mon. U. S. Geol. Survey, vol. 1, 1890.)

1,000 feet above the present level of Great Salt Lake. Its shore line had many irregularities, and, exclusive of the islands, had a total length of about 2,550 miles. Promontories, peninsulas, islands, bays, and straits existed in abundance, for the Basin ranges were con-

[1] U. S. Geog. and Geol. Surveys W. 100th Mer. [Wheeler Survey], vol. 2, 1875, p. 88.

verted into rocky peninsulas and islands, and the intervening low areas into bays and straits.

The main body of Lake Bonneville was north of Juab County, covering Great Salt Lake Desert, but at its highest stage approximately 5,000 square miles, or one-fourth of its total area, lay within the three counties here considered. If the lake existed at present Deseret would be covered by 600 feet of water; Nephi, Oak City, Holden, Fillmore, and Kanosh would be at or near the shore, while Joy and Utah Mine would be situated on islands. The outline of the lake when it stood highest (known as the Bonneville stage) is shown in figure 2.

When the lake reached the Bonneville stage it found an outlet toward the north at a point where several hundred feet of uncemented alluvium rested on indurated limestone. The outflowing stream rapidly swept away the alluvium and as rapidly lowered the lake level; but when it reached the limestone downward cutting progressed very slowly and the lake consequently stood at virtually one level for a long period. This long period is known as the Provo stage, and the prominent shore line formed at this time is known as the Provo shore line. At the Provo stage the lake stood about 375 feet lower than at the Bonneville stage, but it still covered a large part of Sevier Desert, Fish Springs Valley, and White Valley, as is shown in figure 2. Eventually, when more arid conditions returned, the lake fell below the level of its outlet and shrank little by little until it dwindled to its present insignificant dimensions. More or less distinct shore lines were formed at a number of levels, but the two that can generally be recognized in the area here considered, and that are significant in discussing ground water conditions, are those that mark the Bonneville and Provo levels.

Volcanic activity began on a grand scale in the Tertiary period and has continued almost to the present day. Some of the lava was extruded so recently that it remains almost untouched by the weather.

## RAINFALL.

### GEOGRAPHIC DISTRIBUTION.

Rainfall observations have been made for the United States Weather Bureau at the stations in Juab, Millard, and Iron counties as shown in the following table.

Rainfall data are comparatively abundant for the belt adjacent to the Plateau province, but are meager for the large desert area comprising the greater part of these counties, and are entirely wanting for the lofty mountain regions.

*Precipitation (in inches) in Juab, Millard, and Iron counties, Utah.*

| Years. | Station. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Nephi. | Levan. | Scipio. | Oak City. | Fillmore. | Black Rock. | Deseret. |
| 1891 | | | | | | | |
| 1892 | | | | | | | 9.47 |
| 1893 | | 15.75 | | | 15.59 | | 7.66 |
| 1894 | | 17.73 | | | 13.37 | | 8.01 |
| 1895 | | 26.12 | | | 16.36 | | |
| 1896 | | 12.37 | 13.62 | | 11.16 | | |
| 1897 | | 16.79 | 19.24 | | 17.04 | | |
| 1898 | | 15.67 | | | 14.59 | | |
| 1899 | | 17.43 | 15.52 | | 14.48 | | |
| 1900 | | 10.34 | 6.92 | | 9.32 | | 5.38 |
| 1901 | | 13.31 | 12.69 | | 12.88 | 7.61 | 9.01 |
| 1902 | | 12.49 | 11.75 | | 11.90 | 6.38 | 4.85 |
| 1903 | | 12.58 | 11.01 | | 11.97 | 13.36 | 6.99 |
| 1904 | | 16.26 | 12.58 | | 12.14 | 6.39 | 7.14 |
| 1905 | 14.62 | 16.24 | 21.13 | | 16.16 | | 9.76 |
| 1906 | 22.34 | 23.84 | 19.99 | 19.05 | 21.28 | | 11.77 |
| 1907 | 18.00 | 20.09 | 18.03 | 14.24 | 17.14 | | 9.64 |
| 1908 | 16.84 | 18.22 | 15.97 | | 18.43 | | |
| Average | | 16.58 | 14.87 | | 14.61 | 8.43 | 8.15 |

| Years. | Station. | | | | | |
|---|---|---|---|---|---|---|
| | Callao and Trout Creek.[1] | Garrison. | Parowan. | Cedar City. | Lund and Enterprise.[2] | Modena. |
| 1891 | | | 14.24 | | | |
| 1892 | | | 11.00 | | | |
| 1893 | | | 12.80 | | | |
| 1894 | | | 12.97 | | | |
| 1895 | | | 12.07 | | | |
| 1896 | | | 9.17 | | | |
| 1897 | | | 18.47 | | | |
| 1898 | | | 13.82 | | | |
| 1899 | | | 10.92 | | | |
| 1900 | | | 7.04 | | | |
| 1901 | | | 11.05 | | | 9.24 |
| 1902 | | | 9.02 | | | 5.09 |
| 1903 | | 4.75 | 11.89 | | 9.36 | 6.93 |
| 1904 | 7.77 | 7.21 | 11.32 | | | 9.83 |
| 1905 | | 8.82 | 13.47 | | | 12.39 |
| 1906 | 12.34 | | 20.87 | | | 19.06 |
| 1907 | 8.28 | 4.35 | 13.73 | 16.16 | | 12.80 |
| 1908 | | | 11.80 | 13.73 | 16.97 | 16.62 |
| Average | | 6.28 | 12.54 | | | 11.50 |

[1] Callao in 1904; Trout Creek in 1906 and 1907. [2] Lund in 1903; Enterprise in 1908.

These records show the heaviest rainfall in the valleys at the foot of the lofty mountains and plateaus along the east margin of the region and much lighter rainfall in the extensive desert area to the west. Thus the average annual precipitation is 16.58 inches at Levan, 14.87 inches at Scipio, and 14.61 inches at Fillmore, but only 8.15 and 8.43 inches, respectively, at Deseret and Black Rock, and only 6.28 inches at Garrison. Apparently the semiarid conditions found at Levan, Scipio, and Fillmore exist over a relatively small area, while the truly arid climate indicated at Deseret, Black Rock, and Garrison prevails over the greater part of the region.

Though no observations are recorded for the lofty mountains and plateaus, the character of their forests and other vegetation makes it

evident that they have more precipitation than the lowlands. This is true of the Wasatch Mountains, the San Pitch Mountains, and the Canyon and Pavant ranges, in eastern Juab and Millard counties;

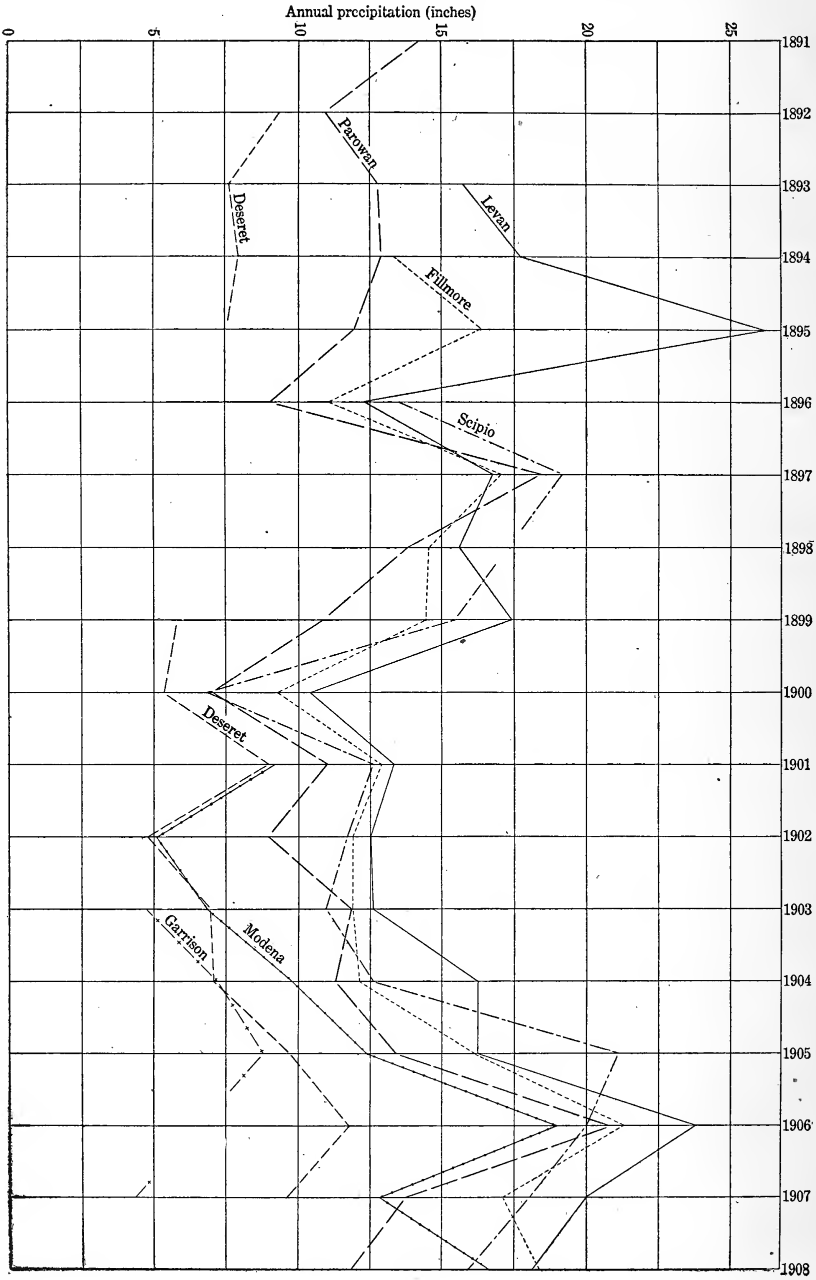



FIGURE 3.—Diagram showing annual precipitation at stations in Juab, Millard, and Iron counties, Utah.

of the Colob and Markagunt plateaus, in eastern Iron County; of the Deep Creek Range, in western Juab County; and to some extent of the West Tintic and other mountains. But the dry and barren condition of most of the low Basin ranges indicates that these ranges receive little more rainfall than the surrounding desert.

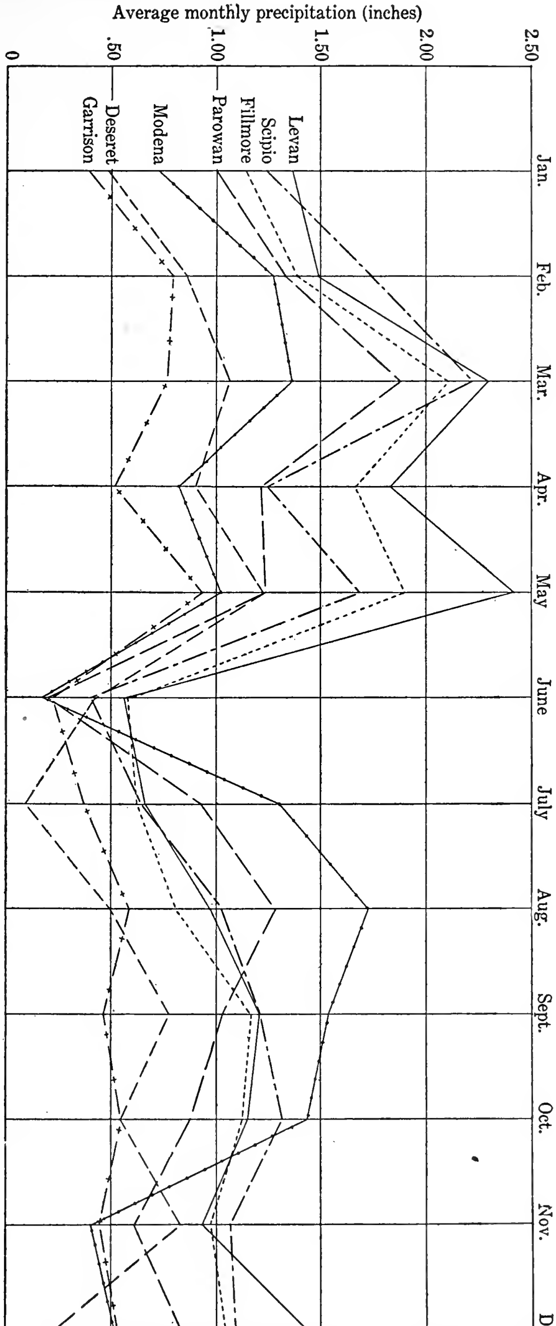



FIGURE 4.—Diagram showing average monthly precipitation at stations in Juab, Millard, and Iron Counties, Utah.

ANNUAL VARIATION.

The precipitation varies greatly from year to year. Thus the recorded range is between 26.12 and 10.34 inches at Levan, between 21.13 and 6.92 inches at Scipio, between 21.28 and 9.32 inches at Fillmore, between 11.77 and 4.85 inches at Desert, between 20.87 and 7.04 inches at Parowan, and between 19.06 and 5.09 inches at Modena.

In general these variations are regional rather than local, as shown by figure 3, in which there appears a general agreement between the curves of the different stations. At all stations where observations were made the precipitation in 1900 was

below the average, and at all but one it was the lowest recorded. In 1906 the precipitation was everywhere above the average, and at all but two stations it was the highest ever recorded. For the region as a whole, the precipitation was below the average in 1896 and above the average in 1897, after which it decreased each year until 1900. From 1901 to 1904 it was somewhat higher than in 1900, but still below the average. In 1905 it was slightly above the average; in 1906 it was exceptionally high; and in 1907 and 1908 it was somewhat lower than in 1906, but still well above the average.

Though the variations from year to year are for the most part regional, yet some remarkable local variations occur, as for example, in 1903 the rainfall at Black Rock was heavier than at Levan or any other station.

### SEASONAL VARIATION.

The precipitation is distributed unequally through the year, as is shown by figure 4, in which, for each station having a sufficiently long record, the average for each month is represented. In Juab and Millard counties the most rain falls in the months of March, April, and May, and the least in June and July. In Iron County (Parowan and Modena) the distribution is somewhat different, the spring rainfall being relatively less and the late summer rainfall distinctly greater. In this respect climatic conditions in Iron County to some extent resemble those in New Mexico and Arizona, where the principal rainy season is in the latter part of the summer.[1]

### RELATION OF RAINFALL TO DRY FARMING.

Until recently farmers have relied almost entirely on irrigation, but in the last few years many attempts have been made to raise crops without artificial application of water. Dry farms conducted on a large scale have been established in Juab, Dog, Little, and Pavant valleys, and in the southeastern part of Escalante Desert, and dry farming on a smaller scale has been undertaken in the other valleys along the east side of the region, and even in the vicinity of Deseret and at Ibex, west of Sevier Lake. In Juab Valley good crops of wheat have been raised without irrigation;[2] in the other localities dry farming was still largely in the experimental stage in 1908, when the region was visited. The weather data show that Levan, in Juab Valley, receives a little more rainfall than the stations in the other valleys along the east side, and much more than those in the desert to the west. They also show that the region in

[1] Henry, A. J., Climatology of the United States: U. S. Weather Bureau, Bull. Q, 1906, p. 50.

[2] See Farrell, F. D., Dry-land grains in the Great Basin: Circular 61, Bur. Plant Industry, U. S. Dept. Agr., 1910.

general received more than an average amount of rainfall during 1906, 1907, and 1908.

## SOIL.

This region contains much more arable land than can be irrigated with the supply of water that is now available or that would be available if all the water resources were fully developed and conserved. Nevertheless, the arable land comprises only a fraction of the total area. It does not include the mountain regions, the lava fields, the gravelly upper portions of the alluvial slopes or bench lands, the sandy dune-covered belts, nor the low, swampy tracts. The best agricultural land is found on the middle portions of the alluvial slopes, below the zone of the coarse gravel and above the alkali.

The soil of the low tracts is almost everywhere impregnated with harmful quantities of alkali. The surface water coming from the higher regions accumulates in these low tracts and the water that sinks into the ground on the higher lands returns to the surface here, both to be disposed of by evaporation. In their contact with the earth both surface and ground waters take up small quantities of soluble mineral matter (alkalies), which they leave behind when they evaporate. Hence, by a slow but long-continued process the soluble substances disseminated through the soil and rocks of the upland regions become concentrated in the lowlands until they exist in amounts injurious to ordinary plants.

The character of the vegetation and in many places the incrustations at the surface show that the low central axes of nearly all the valleys and the extensive low flats of Great Salt Lake Desert, Sevier Desert, and Escalante Desert have alkali soils. Even in valleys that have outlets, such as Juab Valley, Little Valley, and parts of Rush Lake Valley, the discharge is so sluggish and (except in Little Valley) so intermittent and the evaporation is comparatively so great that alkali has accumulated. The largest tracts of alkali soil are the desert flats which for a long time were covered by the waters of a salt lake and which lie so low that in some places the ground water still comes to the surface and evaporates. In the detailed descriptions of Sevier Desert, Wah Wah Valley, and Escalante Desert analyses of soil from several localities are given. (See pp. 109–110, 118, and 150–151.)

The fertile land in most localities lies so high that some of the water available for irrigation can not be brought to it without pumping. In order to utilize this water, low land is cultivated and consequently the presence of alkali becomes a source of trouble. This trouble is perhaps greatest on the low flat in the vicinity of Deseret, where water from Sevier River is used. Two remedies are here available, both of which are now under consideration. One is to install a drainage system, by means of which the alkali can be

washed out of the soil; the other is to divert the water so far upstream that it can be conducted by gravity to higher and better land.

Outside of Sevier Desert the principal difficulties with alkali are experienced where irrigation is attempted with water from springs or wells. A number of large springs in Snake Valley and Fish Springs Valley, the large springs near Clear Lake, and many smaller springs and seeps in Pavant and other valleys are used for irrigation, but the crops produced are insignificant when compared with the amount of water applied, the difficulty being that the water issues at low levels, where the soil contains alkali. Likewise nearly all the wells in which the water rises to the surface or nearly to the surface are on low ground, and irrigation with well water is generally accompanied by trouble with alkali.

## VEGETATION.

The native vegetation is an index to the character of the soil and climate of the region.

The mountains and plateaus that are high enough to receive a copious fall of rain and snow are covered with forests of yellow pine, fir, quaking asp, birch, maple, cottonwood, scrub oak, and other trees and shrubs; but the arid Basin ranges and volcanic buttes and mesas support few trees, except stunted conifers such as scrub cedar, juniper, and piñon pine, and the broad valleys and deserts are treeless, except for clumps of cedar and piñon on the upper parts of some of the alluvial slopes, a few dwarfed willows in the vicinity of springs, and cottonwoods or other species planted in the irrigated oases.

On the alluvial slopes of the valleys in the eastern part of these counties, large and luxuriant sagebrush (*Artemisia tridentata*) predominates, and along dry runs, where it receives a comparatively plentiful water supply, without being subjected to alkali or swampy conditions, this brush grows to treelike proportions.

Farther west the more arid climate is clearly reflected in the more scanty vegetation, the large sagebrush being replaced by stunted individuals and by smaller species. Here the bush known as shadscale becomes common, and in many localities it is dominant.

In extensive low tracts, where the climate is arid and the soil contains alkali, but where the ground water is near the surface, greasewood is present almost to the exclusion of other plants. Under favorable conditions the greasewood rivals in size the most luxuriant sagebrush, and where it is well watered its rich green aspect contrasts strongly with the monotonous grayish-green hue which the sage and shadscale give to most of this country. In localities where there is some natural irrigation but where the soil does not contain excessive quantities of alkali greasewood may be supplanted by rabbit brush; in areas having an alkali soil, but greater depth to water, it is likely

to give way to shadscale; and in swampy districts heavily impregnated with alkali it yields to saltbrush.

Forage grasses grow on the well-watered mountains and plateaus and in meager quantities on the more arid Basin ranges and in the valleys and deserts. Swampy areas watered by springs and seeps may produce a large growth of grass, which, however, is poor in quality. Some forage is also supplied by a small plant locally known as black sage and by greasewood and other bushes. The entire region is placed under tribute for grazing, though the number of acres necessary to feed one animal is large. Horses and cattle are raised, but most of the range, especially the driest part, is used for sheep. In the summer most of the sheep are kept on the high plateaus, but in the winter they are brought into the desert.

Cacti occur in this region, but are not abundant. They are found in the largest numbers in southern Iron County. Tules or other rushes grow at the margins of some of the springs, and water-cress thrives in the large springs and their effluent streams, especially in Snake Valley. The Hot Springs near Fish Springs and the Hot Springs in the River Bed region support filimentary algæ of various colors.

In the low parts of some of the deserts and valleys there are extensive alkali clay flats that are destitute of vegetation of any kind. These flats remain intensely dry for long periods, but are occasionally inundated, and it seems that none of the desert plants can adapt themselves to such extremes.

## STREAMS.

Sevier River is the only large stream that enters this region. It rises on the plateaus of Iron and Kane counties and flows northward a long distance through a structural trough that lies just beyond the eastern boundary of Iron, Beaver, and Millard counties. Eventually it turns to the west, crosses into Juab County, traverses Little Valley, and escapes through Sevier Canyon, at Leamington, into the desert, across which it meanders to Sevier Lake. Much of the water is diverted for irrigation before the river reaches the region described in this paper, but a part is used by the settlements in Sevier Desert and a part still escapes into Sevier Lake, where it evaporates.

Many small disconnected streams rise in the highlands along the eastern border of these counties, descend with steep gradients through rock-bound canyons, and emerge on the arable alluvial slopes, where their waters are used for irrigation. During the spring months they are supplied largely by the melting of snow at high altitudes and their flow is therefore relatively copious. Later in the season, when all or nearly all of the snow has disappeared, they shrink greatly and the smallest creeks become dry. The streams that

head in the highest mountains are fed from melting snow until late in the summer, but those that drain less lofty ranges and plateaus dwindle long before the crops mature. Heavy rains may fall at any time and give rise to swollen, torrential streams that rush down the canyons and across the alluvial slopes. If storage facilities could be provided whereby the flow of these streams could be controlled and the water they discharge each year could be applied to crops when needed, much more land could be irrigated. Unfortunately neither the narrow canyons with their steep grades nor the open alluvial slopes afford good reservoir sites, and little has been accomplished in the way of storing water.

The areas receiving these small mountain streams are Juab Valley, in Juab County, Round Valley and the areas west of the Canyon and Pavant ranges, in Millard County, and Parowan and Rush Lake valleys, in Iron County. The Wasatch Mountains and San Pitch Mountains give rise to streams that flow into Juab Valley, the largest of these being Salt Creek, which emerges at Nephi. The Canyon Range is drained chiefly toward the west and on the west side rise several streams, the largest of which is Oak Creek. The west flank of the Pavant Range is drained by numerous streams, among which Chalk Creek and Corn Creek are the largest. The streams originating on its east flank all flow into Sevier Valley, except Ivie Creek, which rises at the head of Upper Round Valley and furnishes the irrigation water at Scipio. The high plateau in eastern Iron County gives rise to a series of streams that discharge into Parowan and Rush Lake valleys, the largest being Parowan Creek and Coal Creek. Further statements in regard to these streams will be found in the detailed descriptions.

In the remaining parts of these three counties there are only a few small streams. In Juab County, Cherry Creek, Judd Creek, and several still smaller streams rise in the West Tintic and Simpson mountains, and a number of creeks flow from both sides of the Deep Creek Range, but in the area intervening between the Simpson and Deep Creek mountains, covering a stretch fully 50 miles long, there are no streams except such as flow from the Fish Springs. In Millard County the only streams between Sevier River and the Nevada line are a few creeks that flow into Snake Valley from the west. The highlands south of Iron County give rise to Shoal, Meadow, and Pinto creeks, which flow toward Escalante Desert, and the Iron Mountains give rise to several small creeks, but the entire north-central and northwestern sections of Iron County are destitute of streams.

## INDUSTRIAL DEVELOPMENT.

The region under consideration supports a population of about 20,000 people, or approximately $1\frac{1}{2}$ persons per square mile. But the

geographic controls of human existence and industrial development are so rigorous that the inhabitants are very unequally distributed, and any statement of average density of population has little significance. The two important controlling factors are (1) water for irrigation and (2) ore deposits.

Most of the inhabitants live at the foot of the highlands along the east margin of the region and depend on the numerous small streams that issue from these highlands. There is a settlement at the mouth of nearly every canyon that has a stream, and the size of the stream is a good index to the size of the settlement, or vice versa. Relatively large streams, such as Salt Creek, Chalk Creek, Corn Creek, Parowan Creek, and Coal Creek, support large settlements, such as Nephi, Fillmore, Kanosh, Parowan, and Cedar. Smaller streams, such as Oak Creek, Summit Creek, Shirts Creek, and Kanarra Creek, support smaller settlements, such as Oak City, Summit, Hamiltons Fort, and Kanarraville. Very small streams, such as Little Salt Creek, Fools Creek, and Cove Creek, support only a few families or a single ranch each. In some places, as at Holden, the water from several streams is led to one settlement, or farmers live in settlements at some distance from their fields and water supply.

Next in agricultural importance to the settlements just described are the communities and ranches that depend on water from Sevier River, including Leamington, the McIntyre ranch at the station of Mack, Burtner, Oasis, Deseret, Hinkley, Abraham, and the Swan Lake farm. Next to these in importance are the communities and ranches in Snake Valley, including Burbank, Garrison, a series of ranches between Garrison and Trout Creek, two ranches at Trout Creek, and three ranches at Callao.

The rest of the region, comprising by far the largest area, is so nearly destitute of water supplies that it contains only a few widely scattered ranches, most of which depend, in whole or in part, upon live stock raised on the range. Ranches of this kind are McIntyre's ranch in Tintic Valley; Rockwell's ranch, on Cherry Creek; Laird's ranch, at Joy; Thomas's ranch, at Fish Springs; James's ranch, at Black Rock; the Clear Lake farm, at Clear Lake station; Ward's ranch, at Rush Lake; and Duncan's ranch, McConnell's ranch, and the Church ranch, in or near the Iron Mountains.

Agricultural establishments of another type that should be mentioned, although they include few permanent settlers, are the large dry farms such as the Utah Arid farm in Dog Valley, and the Juab Development Co. farm in Little Valley.

Approximately one-fourth of the inhabitants of the region are found in mining camps and are dependent in some way on the mining industry. The great majority of these are in the Tintic mining

district, but there are small camps at Fish Springs and Joy, in Juab County, and at Stateline, in Iron County, and prospectors are scattered through the region. Ore deposits are of course located without reference to the present occurrence of water, and the problem of providing a water supply for mines and mining communities may be difficult, as it proved to be in the Tintic district. The mining industry has an important influence on agriculture by creating a demand for agricultural products.

The main line of the San Pedro, Los Angeles & Salt Lake Railroad passes diagonally through this region. Along its entire course, however, it is at some distance from the villages on the east side, its route having been determined by the location of mines and by engineering considerations. A branch line passes through Juab Valley, but the villages in the eastern parts of Millard and Iron counties are remote from any railroad connections. This position of the railroad has brought a certain amount of human life and activity into a desolate desert tract. Oasis, Clear Lake, Black Rock, Lund, and Modena have only a few inhabitants, but they are the supply points for nearly the entire region except eastern Juab County. Incidentally, this position of the railroad required a water supply in the desert tracts and resulted in valuable underground explorations.

The uninhabited condition of a large portion of these counties can best be shown by an example. In that part of Millard County which lies between Black Rock and the Sevier Desert settlements on the east and Snake Valley on the west the only inhabitants are two men, who are at Ibex a part of the time. Yet this is a region of diversified topography, 50 miles wide and 65 miles long, comprising about one-half of Millard County, and is as large as Rhode Island and Delaware combined. Its only product of economic value is a scanty growth of forage plants, which are picked up by flocks of sheep brought thither in the winter season.

The physical conditions and natural resources of the region are distributed in a way that has resulted in producing three types of communities whose people have important differences in character and mode of life; these are the irrigation settlements, the isolated ranches, and the mining towns. The irrigation settlements were founded long ago by the Mormons, and the inhabitants have been powerfully influenced by geographic conditions. Their sociability and hospitality, their simple habits and elemental morals, and their spirit of contentment and general lack of commercial enterprise have no doubt been in large part engendered by the physical conditions that threw them into small, compact, isolated communities, having a comparatively secure livelihood but rigid limitations to industrial expansion.

## OCCURRENCE OF GROUND WATER.

### BEDROCK.

#### WATER IN SEDIMENTARY ROCKS.

The indurated rocks comprise limestone, quartzite, conglomerate, sandstone, and shale. The quartzite and hard gray limestone of Paleozoic age are widely distributed, but the conglomerates, sandstones, and shales of younger systems are found mainly along the east margin—in the mountains east of Juab Valley, in the Valley Range and the ridges on both sides of Chicken Creek, in the Canyon and Pavant ranges, in the high plateaus east of Parowan and Rush Lake valleys, in the low range west of Parowan Valley, in the Iron Mountains, and in the highlands farther southwest.

The body of the Paleozoic quartzite and limestone is compact and impervious, but small quantities of water penetrate these rocks through joints and fracture zones; the sandstones and conglomerates, where not too firmly cemented, carry water in the pore spaces; the shale beds contain little water.

If the indurated sedimentary rocks had a favorable topographic attitude they would no doubt furnish moderate supplies of water in many localities, but their attitude is almost everywhere unfavorable for recovering water by sinking wells into them. On the uplands the water that seeps into these rocks is likely to be returned to the surface where the strata outcrop or to penetrate to great depths; on the lowlands the bed rock is buried beneath such thick accumulations of unconsolidated sediments that it can in most places be reached only by very deep drilling. As a result of these conditions little water is obtained from the indurated sedimentary rocks except such as issues in mountain springs, and but few attempts have been made to procure supplies by drilling into these formations.

In the Tintic mining district, in the East Tintic Mountains, a number of shafts have been sunk through Paleozoic limestone to depths of 1,500 to 2,260 feet, or several hundred feet below the water level in the unconsolidated sediments of the adjacent Tintic Valley, without finding any water, and one or two deep mines have encountered small amounts of water at levels considerably below the water level in the valley.

In the Utah mine, which is situated near the north end of the Fish Springs Range and is developed mainly in Paleozoic limestone, no water was found until the workings reached the 800-foot level, which is lower than the Fish Springs and the ground-water table of the plain bordering the mountains. Even at this depth the supply is very small.

In the valley north of Fillmore there is a low ridge consisting in part of quartzite and in part of deep red and blue shale and sand-

stone—the same formations as are found in the Pavant Range. It is nearly buried beneath unconsolidated sediments and forms one of the exceptional localities of this region in which the indurated sedimentary rocks are near the surface and yet not far above the general ground-water level. Here several wells have been sunk, the first to test for artesian water and the rest in search of oil. It appears that the rocks were found to contain considerable quantities of water which is of satisfactory quality and rises within a short distance of the surface. But even here the rocks apparently do not afford more favorable conditions than the unconsolidated sediments, and drilling in them is more expensive.

Near the southern boundary of Iron County, in the vicinity of Enterprise, a test well, drilled to a depth of about 700 feet, is reported to have entered 400 feet of red rock. The rock here also contains water, but according to report it was less in quantity and lower in head than the water in the overlying beds of sand and gravel.

In the southern part of Juab Valley, near the west ridge, which here consists of eastward dipping conglomerates, sandstones, and other rocks of probable early Tertiary age, a well was drilled to a depth of 620 feet, chiefly in rock. The first satisfactory supply found in this well was near the bottom, from which level the water rose to within 22 feet of the surface.

## WATER IN IGNEOUS ROCKS.

The igneous rocks include ancient granite, Tertiary intrusives and extrusives, largely of acidic or intermediate composition, and more recent volcanic material, chiefly basalt. The ancient granite lies at the surface in only a few mountainous districts, but it has been reached in deep drilling in Lower Beaver Valley and it no doubt exists far below the surface in other localities. Igneous rocks of Tertiary or more recent age occur in large quantities in the East Tintic Mountains, the Thomas Range, the buttes and mesas of Sevier Desert and of the southeastern part of Millard County, the mountains of eastern Beaver and Iron counties, the low ranges of western Iron County, and in other localities.

The railroad wells at Goss and Neels are reported to have penetrated granite at depths of 1,643 feet and 1,950 feet, respectively, and the Goss well is said to have found great quantities of salty water in crevices of this rock. It is, however, not probable that the granite would generally yield water even where it is within reach of the drill.

The Tertiary igneous rocks are for the most part compact and impervious, but the mining developments in the Tintic district have shown that, at least in that locality, they are ramified by fracture zones which permit a slow seepage to depths of hundreds of feet but

which are not open enough to allow the water to escape quickly, as in fractures in the limestone of the same district. The mines in the igneous rocks, none of which exceed a few hundred feet in depth, contain water, but those in limestone are dry or do not find water until they reach great depths. Moreover, mines that pass through igneous rocks into underlying limestone seem to lose their water when they enter the limestone.

Near the surface the igneous rock disintegrates to form coarse-grained porous débris into which the water that falls as rain can penetrate. Since this débris rests on undecomposed igneous rock that is nearly or quite impervious, the water is prevented from escaping downward, and where the topography is such that it can not readily drain away, it may accumulate and give rise to springs or seeps or afford a supply for shallow wells.

The quantity of water that can be obtained from the disintegrated mantle of the igneous rock or from the fracture zones that penetrate this rock to greater depths is invariably small, but it is nevertheless of great value in localities where no other water is available. In many places supplies from such a source can be increased by increasing the infiltering surface, either by digging more wells of large diameter or by constructing tunnels or infiltration galleries below the water level. Little or nothing can be accomplished by deep drilling.

The most extensive developments of this kind have been made in the Tintic district, where the public supply for the city of Eureka, the supply for one of the railroads, and the supplies for a number of mines are obtained from pumping plants which draw from the partly disintegrated igneous rock and the overlying rock waste. Supplies of this character have also been developed at Joy and elsewhere.

A number of springs of fair size exist in those parts of the East Tintic Mountains in which the surface formation consists of igneous rock (Pl. V), and the water from some of them is conducted through pipe lines to Silver City, Jericho, and the Utah Arid farm. Small springs of similar character found in the low mountains of western Iron County, where igneous rock underlies the surface débris, provide valuable watering places for live stock on the range.

The more recent basaltic lavas are in many places broken by joints and fissures, through which water can pass freely and through which it may escape at low levels in large springs. Examples of groups of springs that appear to be of this type are the Black Rock Springs, the Clear Lake Springs, the Hot Springs north of Abraham, and the springs at Rush Lake, each of which yields at least a second-foot of water. The well at Ward's ranch (near Rush Lake) also derives its water from a crevice in lava rock.

### CONFINING FUNCTION OF BEDROCK.

For the region as a whole, the indurated rocks, both sedimentary and igneous, are not of much importance as water-bearing formations. Their chief value lies in their confining function in the basins which they form and which are partly filled with unconsolidated water-bearing sediments. The small perched basins may allow of so much leakage that their unconsolidated sediments are entirely drained, but the large basins, which are relatively depressed, although high above the level of the sea, are sufficiently waterproof to cause the accumulation of water in the unconsolidated sediments. In this way the rock basins act as huge reservoirs whose supplies of water can easily be drawn upon in the lowland areas, and are, therefore, of great economic value. As the Tertiary igneous rocks are as a rule less permeable than the Paleozoic limestones, the basins underlain by them are more likely to contain water than those underlain by the limestones.

## UNCONSOLIDATED SEDIMENTS.

### CHARACTER OF SEDIMENTS.

The sediments that partly fill the rock basins, thereby forming "valleys" and "deserts," are derived from the mountainous rims of these basins, where the firm rock is subjected to the destructive activities of the weather. Ever since the great deformations which brought the basins into existence the rocks in the uplands have been disintegrating at the surface and the resulting rock waste has been swept away, chiefly by torrential storm waters, and deposited in the low parts of the basins. Hence the serrate peaks and deep canyons and myriad of gullies with which the uplands are sculptured. Hence also the extensive smooth alluvial slopes and desert plains underlain by thick deposits of clay, sand, and gravel.

The stream, lake, and wind deposits which fill the basins are here grouped under the collective name of "unconsolidated sediments" in order to differentiate them from the hard igneous rocks and the ancient indurated sedimentary formations which are together called "bedrock." It should, however, be understood that some of the stream, lake, and wind deposits have become firmly cemented, and that a certain amount of cementation has generally taken place, as is shown by the fact that dug wells are usually not cased above the water level.

The unconsolidated sediments are by far the most valuable water-bearing beds of this region. Nevertheless, they are not good water producers in every locality nor at each horizon, the principal difficulties being (1) that they may be drained of their water, (2) that they may consist entirely of fine-grained materials which will not

surrender water freely, and (3) that they may contain only salty water.

### WATER IN STREAM DEPOSITS.

When a stream escapes from its canyon and its carrying power diminishes it drops the coarsest part of its load first and conveys the finest sediments farthest into the valley or desert. Hence the upper parts of the alluvial slopes consist largely of gravel and bowlders, and the parts most remote from the mouths of the canyons are underlain by beds of clay and fine sand associated with little gravel and no bowlders.

A swollen stream sweeping rapidly down a steep, narrow canyon can move great quantities of gravel and roll along large bowlders, and even on the alluvial slope it is able to carry the coarse parts of its load much farther than when it has only its normal size, bowlders being transported at times of flood to almost incredible distances from the mountains. Hence coarse sediments come to be superimposed on fine sediments, and, in sinking a well, successive beds of clay, sand, gravel, and even bowlders will be encountered.

Since the aggrading streams flowing over the alluvial slopes change their courses frequently, depositing débris now in one locality and now in another, the beds underlying these slopes are not continuous, and wells only a short distance apart may show entirely different sections.

In most localities the stream deposits include beds of sand and gravel that are capable of yielding water freely. As the distance from the mountains increases, the number and thickness of these beds decrease, their constituent particles become smaller, and their yield of water becomes correspondingly less copious; but fairly abundant supplies can generally be obtained even in the valley flats. The principal difficulty in connection with the stream deposits is that in the upper parts of the alluvial slopes the porous beds are drained to great depths, in some places even to the bedrock.

### WATER IN LAKE DEPOSITS.

Since the conditions of sedimentation are much more uniform at the bottom of a lake than on an alluvial slope, the lake beds are more continuous and regular than the stream deposits, and wells in the same vicinity have nearly the same sections. In the quiet waters of a lake the gravel and sand brought by streams sink near the shore and only very small particles that stay long in suspension reach points remote from the shore. Hence lake deposits are likely to consist so largely of beds of clay and fine-grained quicksand that they will yield only meager supplies of water. Especially is this condition imminent near the center of extensive lake beds such as

Great Salt Lake Desert and Sevier Desert. Salt is likely to be deposited in lakes that have no outlet, and the ground water found in the lake sediments may therefore be saline. Both of these unfavorable conditions are encountered in this region.

### WATER IN LOW VALLEYS.

A typical valley of this region consists of a rock trough partly filled with sediments so disposed as to form alluvial slopes on each side with a central flat between. Stream deposits underlie the alluvial slopes but lake deposits may occur at the center. In many valleys the sediments are saturated to the level of the central flat. As new supplies of water are poured out from the mountains and absorbed by the porous gravel of the alluvial slopes the amount of ground water is increased and some of it returns to the surface in the lowest parts of the central flat, either in springs or by imperceptible capillary action, and is removed by evaporation, or, less commonly, flows out of the valley through a drainage outlet. (See fig. 5.) On the central flat and the lower parts of the alluvial slopes the ground water is therefore near the surface and can easily be obtained by sinking wells into the unconsolidated sediments.

The most favorable location for wells is at the base of an alluvial slope where the surface is not far above the ground-water level but where coarse water-bearing beds are still plentiful, on the side of the valley bordered by the mountains which furnish the most water, and in the vicinity of the largest streams. The wells in the flats generally yield less freely.

Juab Valley, Parowan Valley, and Rush Lake Valley are typical of the kind of valleys just described. Their sediments are saturated to a level controlled by their central flats, and the best wells are obtained near the base of the east slopes, which receive the principal water supplies. Pavant Valley (Holden to Kanosh), Little Valley, Tintic Valley, and Snake Valley are also of this type, though somewhat modified. Each has one or more low tracts along the central axis, where the ground water is returned to the surface, showing the saturated condition of the sediments below the level of these tracts.

### WATER ON DESERT FLATS.

The deserts, like the valleys, are surrounded by alluvial slopes which descend from the upland borders, but they differ from the valleys in having more extensive central flats with a more important development of lake deposits. At the base of the alluvial slopes the conditions are not unlike those found in the valleys, as is illustrated by the wells at Callao, in western Juab County, and those in the vicinity of Enterprise and New Castle, in Iron County. The desert flats, like the valley flats, lie so low that the ground-water level

is near the surface, but they differ from the valley flats in being underlain more largely by non-water-bearing clay and quicksand and by beds that make the water salty.

Sevier Desert includes the Lynn bench and the adjacent low flat (Pl. I). The Lynn bench is a relatively level upland tract formed essentially as the delta of Sevier River in the Provo stage of Lake Bonneville. It consists largely of sandy and gravelly material which absorbs much of the rainfall. At Lynn a successful well was drilled by the railroad company, and good wells could probably be obtained on most parts of the bench. As at Lynn, however, the water level is probably everywhere at some distance below the surface.

At Deseret and the other settlements on the flat near the base of this bench many successful wells have been drilled. Here the sediments consist chiefly of clay and include very little gravel, but there are numerous beds of sand, all of which are charged with water that rises nearly to the surface or a little above the surface. The principal source of supply is evidently the Lynn bench.

Farther southwest, at greater distances from the bench, conditions rapidly become more unfavorable for ground-water supplies. The proportion of clay becomes greater, the sand becomes finer, and the water becomes meager in quantity and so salty that it is generally not fit to use. At Goss station, remote from the Lynn bench, the railroad company drilled through hundreds of feet of dense clay or shale that is almost totally destitute of water.

In brief, the sediments underlying Sevier Desert were supplied chiefly by Sevier River, and consequently they become finer as the distance increases from the mouth of the canyon at Leamington, where the river began to deposit its load. This condition is shown in Plate III. Neels and Goss are situated near the Cricket Mountains (Beaver Range), and it might have been expected that gravel from this range would be intercalated between beds of clay derived from more distant sources, but, according to the well sections, such local materials are almost entirely wanting.

Great Salt Lake Desert extends into the northern part of Juab County, forming the Fish Springs Flat and the flat between the Deep Creek Range and the Fish Springs Range. In the vicinity of Callao, at the base of the large alluvial slope of the Deep Creek Range, a number of good wells have been obtained, but in several holes sunk on the flat near the Fish Springs Range only salty water was found. The western part of this flat may have received some contributions of coarse sand from the streams that drain the Deep Creek Range or from water which in more humid periods probably issued from Snake Valley, but the eastern part of this flat and the entire Fish Springs Flat had no important source of local sediments. At its north end the Fish Springs Range is almost devoid of an

alluvial slope and the lake plain abuts against the rocks. Here conditions similar to those at Neels and Goss might be expected.

White Valley was occupied by an arm of Lake Bonneville during most of the time that the lake existed, but this arm of the lake received no important streams. The extensive central flat of White Valley is therefore probably underlain to a great extent by fine nonwater-bearing lake sediments. Gravelly beds containing water may exist at the margins.

In Escalante Desert the sediments are also predominantly fine but some beds of sand yield water of good quality. Satisfactory wells have been obtained at a number of points in this desert.

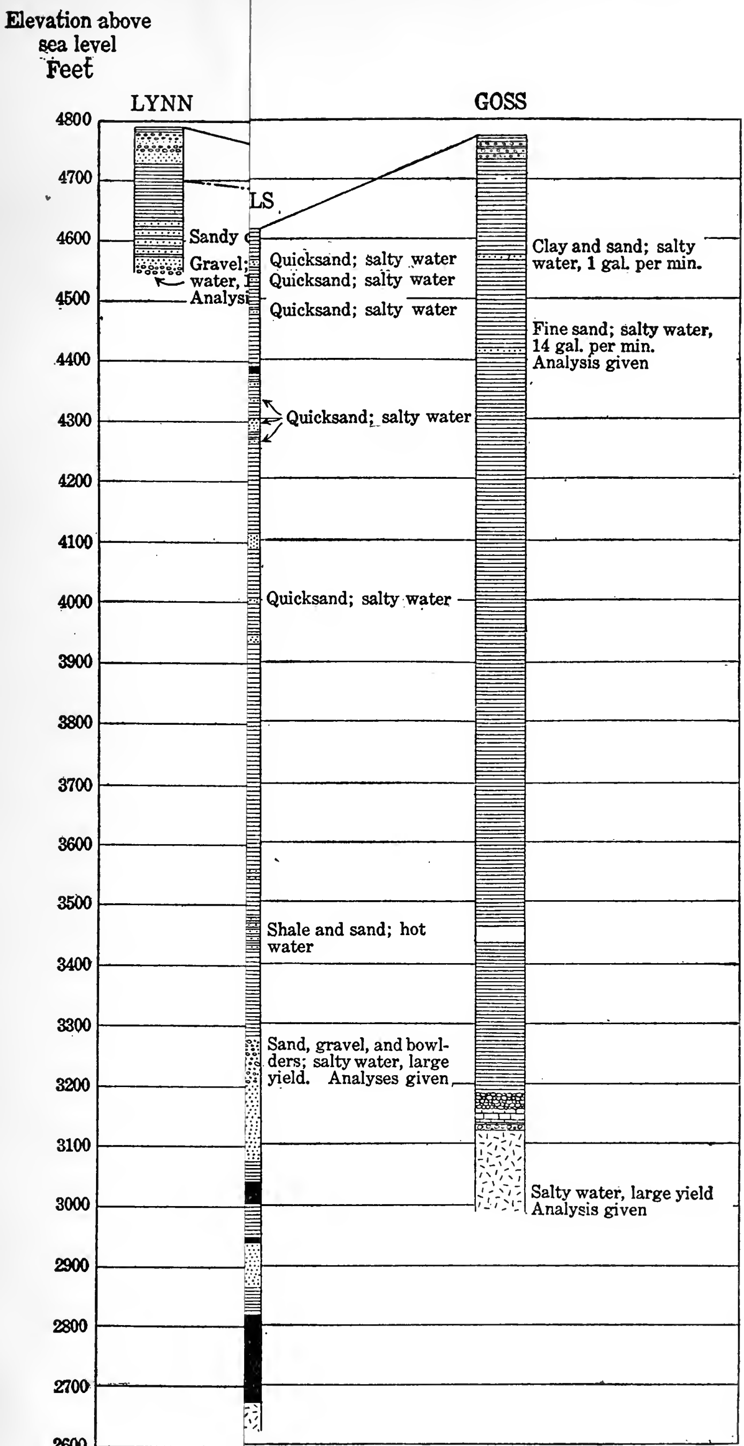
### WATER ON ALLUVIAL SLOPES OR "BENCH LANDS."

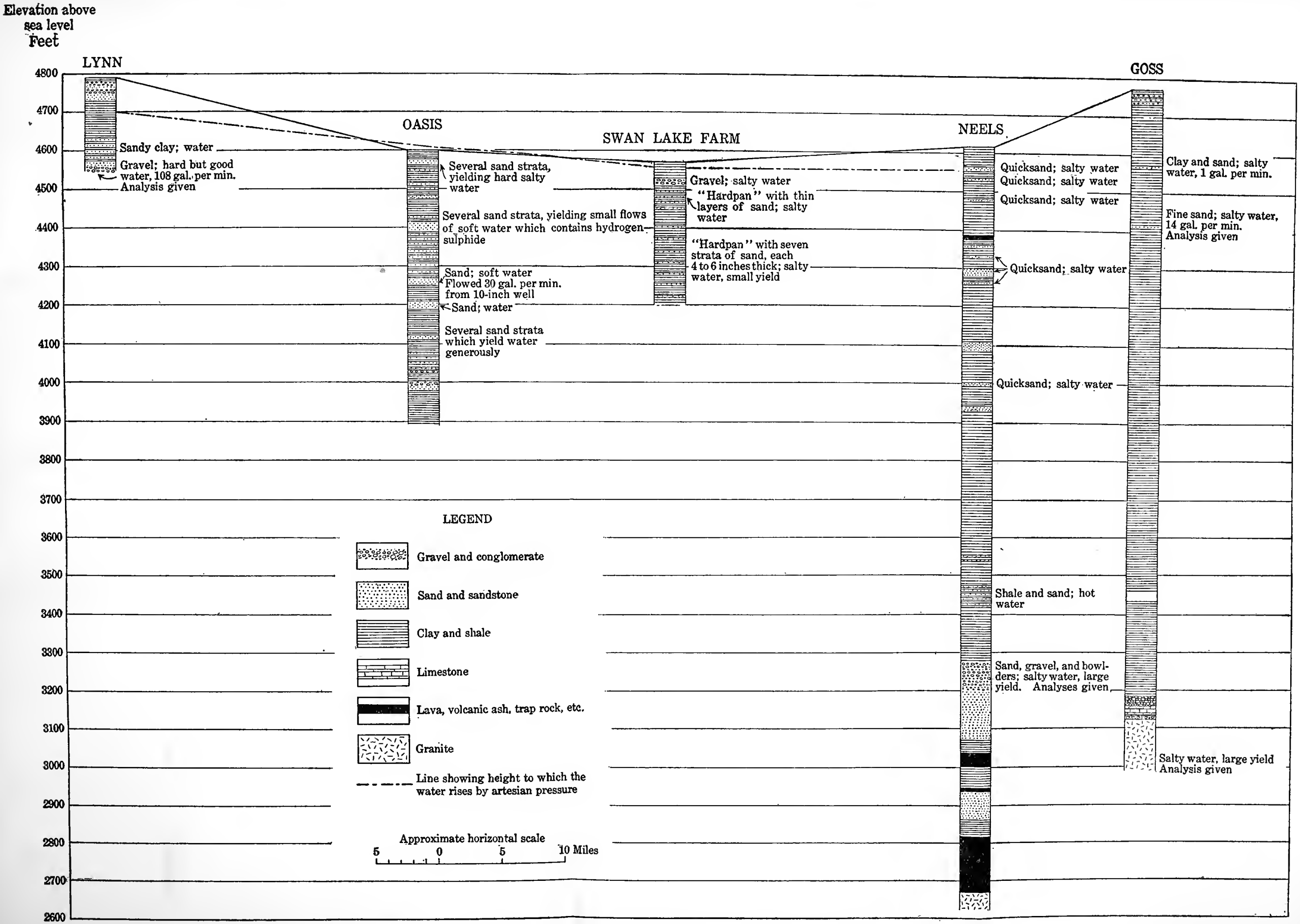
The broad alluvial slopes which generally lie between the mountains and the lowlands comprise a large part of the total area of this region. Near the base of these slopes there are many good wells, as has already been shown, but on the middle and upper parts there are few wells, although many holes have been dug in the quest for ground water. In most of these unsuccessful projects the holes were abandoned before the level was reached at which the normal ground-water table could be expected, and the failure does not indicate the absence of water farther down. The ground-water table slopes upward in the direction of the mouths of the canyons whence the principal supplies of water are derived, but the surface of the land slopes upward much more rapidly. This increase in altitude is seldom taken into full account when a well is sunk.

In the valleys which receive permanent streams and have satisfactory wells in their lower parts the prospects are good for obtaining water by sinking holes some distance farther up the slopes than where the wells now existing are located. But it will generally be necessary to sink to depths of several hundred feet before finding water, and the water will not rise near the surface. Prospecting on the alluvial slopes could be done more effectively with a drilling machine than by digging. (See pp. 58–64.) Springs and crusts of alkali in the low parts of valleys indicate that the water table is near the surface, and hence, like wells, give a basis for estimating the depth to water on the adjacent slopes.

In the dry valleys in the western part of the region, even where springs or alkali flats are present, the prospects of obtaining water beneath the alluvial slopes is more uncertain, and exploration should be confined more closely to the lower parts of the slopes and to the localities where the largest canyons discharge their storm waters.

On the side of a range toward which the rock strata of the range dip there is generally a broad and high slope, as, for example, the slopes on the west side of the Thomas Range and on the east sides of


Elevation above sea level Feet
LYNN
GOSS
LS
4800
4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
Sandy
Gravel;
water,
Analysi
Quicksand; salty water
Quicksand; salty water
Quicksand; salty water
Quicksand; salty water
Quicksand; salty water
Shale and sand; hot water
Sand, gravel, and bowlders; salty water, large yield. Analyses given
Clay and sand; salty water, 1 gal. per min.
Fine sand; salty water, 14 gal. per min. Analysis given
Salty water, large yield Analysis given




WELL SECTIONS IN SEVIER DESERT AND LOWER BEAVER VALLEY.

the House and Confusion ranges. (See Pl. IV.) On these large slopes all the sediments above the rock formations are likely to be dry, and the prospects of obtaining water at any practicable depth are very poor.

In some places where layers of clay alternate with beds of sand and gravel the water is prevented from sinking below the clay layer but percolates along its upper surface. Where such a condition exists small supplies are found unexpectedly near the surface, as, for example, in the wells at Holden. (See fig. 12, p. 92.)

### WATER IN HIGH VALLEYS.

The absence of springs and alkali flats in the lowest part of a valley should be regarded as an unfavorable indication. It shows that the unconsolidated sediments are not saturated to the level of the lowest part of the valley, and it leaves no clue as to whether these sediments contain any ground water or are entirely dry. If the basin is inclosed on all sides and is underlain and bordered by impervious formations, such as the Tertiary igneous rocks, it may contain some water, but if it is only partly inclosed or is underlain by fissured rock, such as the Paleozoic limestones, its water is likely to be drained to lower levels.

The principal regions containing elevated valleys that have no surface indications of ground water are the high country between Juab Valley and Tintic Valley and the mountainous district between Sevier Lake and Snake Valley.

## ARTESIAN CONDITIONS.

### BEDROCK.

The conditions in Juab, Millard, and Iron counties are unfavorable for obtaining flowing wells from rock formations. In most places the strata in the mountains dip away from the adjacent valleys or are so much contorted and broken that they preclude all possibility of giving rise to artesian pressures. In some places they dip toward the valleys, but at so great an angle that they are carried to profound depths before they reach the lowlands where they might furnish artesian water. Moreover, the rocks which might bear water are not generally covered by competent confining beds, or the latter are so greatly faulted and fractured that they are ill adapted for holding water under pressure.

Within this region there is no flowing well that is known to derive its water from bed rock and no locality where the prospects for obtaining flows from rock formations are sufficiently good to warrant the expensive drilling that is necessary to make a test. There is a common fallacy to the effect that where flows are obtained from

the unconsolidated sediments much stronger ones could be secured by drilling deep into the bed rock. In fact, however, artesian conditions in the unconsolidated valley deposits bear no relation to conditions in the deeper lying bed rock, and are not in any sense an indication that flows could be secured by drilling into the deeper solid formations.

## UNCONSOLIDATED SEDIMENTS.

### FLOWS IN THE VALLEYS.

In order to understand the artesian conditions in the unconsolidated sediments it is necessary to recall some of the relations that have already been explained. In many of the valleys these sediments are saturated to the level of the low central flats. (See fig. 5.) New supplies of water are poured into these valleys and sink into the

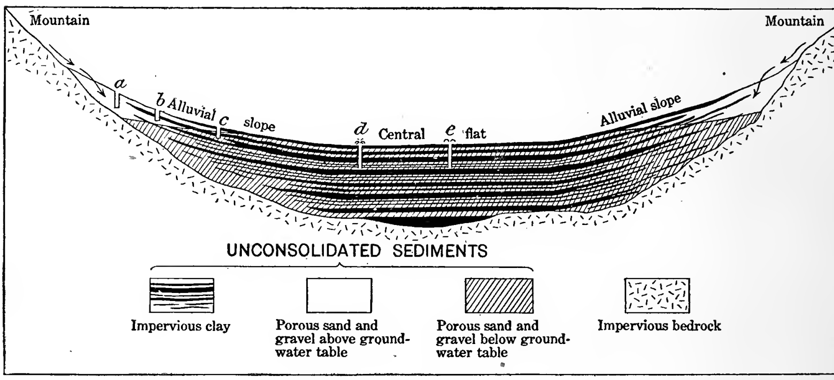



FIGURE 5.—Diagrammatic cross section of a typical valley, showing ground-water conditions: (*a*) Dry hole which if sunk deeper would strike bed rock without finding water. (*b*) Dry hole which would find water if sunk deeper. (*c*) Pump well of moderate depth. (*d*) Strong flowing well. (*e*) Weak flowing well.

gravelly upper parts of the alluvial slopes. Thus the water beneath the slopes accumulates till it stands above the level of the central flats, and consequently moves slowly toward these low flats, where it reappears at the surface and is generally disposed of by evaporation, leaving behind the salts that it had taken into solution in the ground, in this way forming the alkali crusts found in low places.

The unconsolidated sediments consist of gravel, sand, and clay. Beneath the higher parts of the slopes gravel predominates, but farther down in the valley it gives way largely to alternating beds of sand and clay. These beds are nearly level where they lie beneath the central flat, but curve upward where they extend beneath the bordering slopes. (See fig. 5.) The gravel and sand are porous and therefore allow water to percolate through them rather readily, but the clay is so dense that it is relatively impervious to water. The water which sinks into the gravel in the higher parts of the slopes

and travels toward the central flat becomes confined below layers of clay, and the water which accumulates back of it places it under pressure. This pressure may become so great that when the clay layers are punctured, as in drilling, the confined water will escape to the surface, forming flowing wells. (See fig. 5.)

If the clay layers were perfectly impervious the head of water would in many valleys be great enough to produce flows with strong pressure, but in fact they allow the water to penetrate them to such an extent that flowing wells seldom have a head of more than a few feet. For this reason springs, seeps, and alkali flats, by showing that the ground water is under sufficient pressure to escape to the surface, are indicators of artesian conditions. A valley showing no overflow in the low places has poor prospects for flowing wells.

Large, steep alluvial slopes and an abundant water supply from the mountains are also promising conditions for flows. Stronger wells are generally obtained near the base of a slope than farther out on the flat because the slight disadvantage in level is more than counterbalanced by the greater coarseness of the sand and gravel and the closer proximity to the supply.

It is evident from figure 5 that only a small part of the water now stored in the ground would flow out of wells without pumping. It is also evident that the amount of water that can be recovered from flowing wells each year, though dependent upon the annual increment, is probably indicated pretty closely by the amount that annually escapes to the surface in low places. This is far from being the unlimited quantity that is so frequently postulated for artesian basins. Yet it must be remembered that the water that issues in the visible form of springs is probably only a small part of the total amount that escapes. Larger quantities generally come to the surface through capillary pores and evaporate unnoticed or with no other indication of their escape than the alkali that they leave behind.

Flowing wells of the type described are in the north and south basins of Juab Valley, in the north and south basins of Rush Lake Valley, and in Little, Tintic, and Parowan valleys (Pls. I and II). The greatest number are in Parowan Valley and in the north basin of Juab Valley. Nearly all the wells are of small diameter and most of them furnish but little water. Some of the strongest flows are in Parowan Valley, where a few 3-inch wells yield more than 40 gallons per minute each and the total yield in the irrigation season amounts to several second-feet.

More water could probably be recovered from flowing wells in all of the valleys mentioned. Parowan Valley has been developed most extensively; Juab Valley perhaps presents the best opportunities of further development, and Rush Lake Valley also offers a field for further explorations. Pavant Valley (Holden to Kanosh) has been

rather thoroughly prospected and the results have been disappointing. In the low parts of this valley the water rises nearly to the surface, but nowhere have flowing wells of any consequence been obtained. The large alluvial slopes and abundant water supply on the east side appear promising, but the interrupted lava beds on the west side may introduce an unfavorable structure. The drilling done in Snake Valley above Trout Creek likewise failed to obtain flows, although in several wells the water rose nearly to the surface. However, this valley has not yet been thoroughly prospected. There is also a chance for flowing wells in Round Valley, where some prospecting has been done, and they might possibly be obtained in certain restricted localities in the drier valleys of the region.

Wells intended to supply water for irrigation should be made larger and should be sunk deeper into the unconsolidated sediments, where they may discover strong water beds that are not now tapped. The casing should be perforated to admit water at all levels where satisfactory water-bearing beds are found. Many believe that very deep expensive drilling would reach water under phenomenal pressure sufficient to cause it to flow even on the bench lands, but this belief is without foundation and affords no justification for expending public or private funds in attempting to get flowing wells on the upper parts of the alluvial slopes.

## FLOWS IN THE DESERTS.

Over large tracts of the extensive ancient lake bottoms that now form desert flats, such as Great Salt Lake Desert, Sevier Desert, and Escalante Desert, the ground is saturated practically to the surface, and ground water is slowly evaporating. Here wells obtain water under sufficient pressure to rise within a few feet of the surface, or, in certain localities, to flow above the surface. In principle these wells do not differ greatly from the wells in the valleys. Their supply comes from the surrounding alluvial slopes and is imprisoned in beds of sand beneath layers of clay. The areas in which flowing water may be expected as a rule lie close to the base of the large slopes or benches which furnish abundant supplies of water and do not extend to the interior of the deserts, where the surface is slightly lower. However, in the interior areas the sediments are so completely saturated and the water from different horizons comes so near the general desert level that a slight depression in the surface may be sufficient to make weak flows possible.

Flowing wells of this type are found in Sevier Desert, at the margin of Great Salt Lake Desert, and in Escalante Desert. The flowing wells on the Beaver Bottoms, south of Black Rock, nearly all of which lie in Beaver County, can also be included in this class.

In Sevier Desert flowing waters are found in at least two distinct areas—the Deseret area and the Desert Wells area. The Deseret area which is the largest and most important area of flow in the region under consideration, contains several hundred wells whose water either overflows or rises so near the surface that no pumps are required. The second contains only a small group of flowing wells, several miles north of Sevier River, and has not yet been thoroughly explored. Both areas lie near the base of the Lynn bench, from which they are evidently supplied. Promising localities for further exploration are along the foot of the bench east of Oasis and north of the Desert Wells. The extensive sandy upland that reaches from Sevier River nearly to Cherry Creek can hardly fail to provide a copious supply of ground water to the lowland that borders it on the west.

The only flowing wells in that part of Great Salt Lake Desert which extends into this region are in the vicinity of Callao. They are situated at the margin of the desert and derive their waters from the large alluvial slope of the Deep Creek Range immediately to the west. Flows can probably not be obtained more than a few miles east of Callao although the surface descends slightly in that direction.

Two flows have been struck in Escalante Desert—one near the west margin and the other in a low tract in the interior. Flows with slight pressure can probably be obtained in other parts of this desert.

In the desert areas, as in the valleys, stronger flows could be obtained by drilling wells of larger diameter to greater depths and by admitting water at more than one level, but no great increase in head is to be expected from deep drilling.

## SPRINGS.

### MOUNTAIN SPRINGS.

The springs of this region fall into two general classes: Mountain springs and valley springs. The mountain springs include seepage springs and structural springs.

Rain or snow falling on the mountain areas may sink into the disintegrated material that in some localities covers the firm rock and may percolate through this loose surficial material until it reaches a place where it is forced back to the surface by an outcropping ledge of rock. These springs, which may be designated mountain seepage springs, are sensitive to differences in rainfall, and vary greatly in their discharge, as is illustrated by Plate V, in which the flow of a spring of this kind is plotted with the rainfall during the same period.

In the arid basin ranges the principal formations are Paleozoic limestones and quartzites and Tertiary igneous rocks. As the igneous

rocks have fewer fissures and crevices through which the water may escape, and are covered with more rock waste than the limestones and quartzites, most of the seepage springs are found in the areas of igneous rock, as is well illustrated in figure 10 (p. 83).

The water that falls on the mountain areas may not merely sink into the surficial rock waste, but may penetrate the joints, fissures, bedding planes, solution cavities, or pore spaces of the bedrock and descend far beneath the surface. As the relief of the mountain areas is great and the rocks are much deformed, some of these passages lead to the surface at lower levels, where the water that entered them higher up in the mountains gushes forth in the form of springs. This type, which may be designated structural springs, is most common in the sedimentary formations of the mountains that have abundant precipitation. The discharge of such springs is more nearly uniform than that of seepage springs and constitutes an important part of the low-water flow of the permanent streams of this region. A striking example of this class is the Warm Spring at Gandy, in Snake Valley, where a great volume of warm water issues from the face of a limestone cliff.

### SEEPAGE FROM UNCONSOLIDATED SEDIMENTS.

It has been fully explained (pp. 34–36) that in most of the large rock basins, known as " valleys " and " deserts," the filling of unconsolidated sediments is saturated with water to the level of the lowest parts, and that as new supplies are added overflow occurs in these low places. Though much of this overflow is accomplished through minute pores in the soil from which the water is evaporated so promptly that the process is quite unnoticed, some of it is accomplished by a definite flow of water out of larger openings in the ground, forming springs or seeps. Springs of this character do not give a measure of the amount of overflow of the underground reservoirs, but they are important in showing that such overflow is taking place. Like the flowing wells, to which they are closely related in origin, they occur most generally at the base of the alluvial slopes that have copious water supplies and are less common in the interior portions of the flats.

Seepage springs are also likely to occur where the unconsolidated sediments have been eroded, as along stream channels and ancient shore lines. In some such places water is percolating along the upper surface of an impervious layer high above the normal ground-water level, and if the stream or wave erosion has extended down to this layer a line of springs results.

### SPRINGS FROM LAVA BEDS.

It has already been pointed out (p. 31) that the basaltic lavas, which are the youngest igneous rocks of the region, contain joint planes and other openings along which water can percolate with relative freedom; and that where these rocks lie at low altitudes they may give rise to large springs. Black Rock Springs, Clear Lake Springs, the Hot Springs north of Abraham, and some of the springs between Enoch and Rush Lake have been cited as examples of large springs of this type.

### HOT SPRINGS.

Near the surface the temperature of the ground fluctuates with the seasonal changes in the weather, but at a certain depth below the surface the earth and the water which it contains are not affected by these changes but maintain constant temperature, which is approximately the mean annual temperature of the region. The mean annual temperature was found to be 47° F. at Levan (for the period between 1890 and 1903, inclusive) and 51° at Fillmore (for the period between 1892 and 1903, inclusive).[1] At greater depths the rock and the water which it contains become gradually warmer, the increase generally being 1° F. for about 50 to 100 feet of increase in depth. But where hot lava has been brought to the surface or intruded into the older formations the downward increase in temperature is much more rapid, even though the volcanic activity may have occurred many thousands of years ago. Moreover, where the rocks have been deformed heat has been produced by the friction involved, and here the downward increase in temperature may also be rapid. If the temperature of the water that comes from a spring is higher than the mean annual temperature of the region, the spring is, strictly speaking, a thermal spring. The high temperature indicates that the water comes from a deep source or from rocks that have been heated by volcanic activity, by deformative movements, or possibly by some other agency.

This region contains a number of springs whose water is distinctly warmer than normal. The principal ones are the Hot Springs north of Abraham, the Hot Springs, northeast of Fish Springs Range, the Warm Spring near Hatton, the Warm Spring at Gandy, the Big Spring south of Burbank, some of the Fish Springs, and some of the pool and knoll springs of Snake Valley. The Hot Springs north of Abraham and the Warm Spring near Hatton are in close relation to volcanic formations and their water evidently derives its high

[1] Henry, A. J., Climatology of the United States: U. S. Dept. Agr., Weather Bureau Bull. Q, 1906, pp. 833, 834.

temperature from them; the others seem to be related to faults in the rocks and their water is probably warm because it comes from great depths or from rocks that have been heated by deformation.

### POOL AND KNOLL SPRINGS.

Pool and knoll springs include an important class of peculiar springs, typical examples of which are found only in Snake and Fish Springs Valleys, though springs having some of their characteristics are found in other parts of the region. In this class belong the Fish Springs, Devil's Hole, Knoll Springs, Kell Springs, Bishop's Springs (at Foote's ranch), some of the springs between Foote's ranch and Trout Creek, Willow Springs, Redding Springs (in Tooele County), and perhaps the Hot Springs northeast of the Fish Springs Range. The location of most of these springs is shown in Plate IV, and all except Redding Springs are described in the sections of this paper dealing with Fish Springs Valley and Snake Valley (pp. 124–126 and 129–133). Many of them yield warm water, and have already been mentioned in the discussion of hot springs.

They are of two types, which differ completely in their external appearance but occur in close proximity to each other and are evidently related in origin. The pool springs are large deep reservoirs filled with clear water, and many of them are inhabited by small fish. At the top the reservoir or pool is bordered by a shelf that extends over the water surface, giving the pool somewhat the shape of a jug or cistern. The shelf appears to be composed largely of a felt-work of vegetable fibers and to be formed by the joint work of plants and wind. The plants at the margin extend inward across the face of the water producing a tangle in which the wind deposits sand and dust. In this manner a soil is formed on which the plants can develop further and close in still more on the water area. Chemical precipitates from the water form no important part of these shelves.

The knoll springs consist of mounds or knolls, in few places more than 10 feet high, from the top or sides of which water flows. The knolls appear to be a development of the shelves of the pool springs. They yield less water than the pool springs in the same locality, evidently because the water is under less head. Thus there appears to be a limit to the growth of the knolls, and their construction involves the decline of the springs that have given them origin.

That these springs are not merely the return to the surface of water that percolates into the sediments of the adjacent alluvial slopes seems to be shown by the following facts: First, the yield of many of them is larger than would be expected if they were supplied from local sources; second, their yield is nearly uniform,

though that of ordinary valley springs fluctuates with the season; third, their location differs from that of ordinary valley springs, the Hot Springs and the Fish Springs, with their copious flow, being near the end of a narrow and dry range, with almost no alluvial slope, and some of the largest springs of Snake Valley, such as those at Foote's ranch, being on the east side of the valley, where relatively little water is supplied by the low, dry Confusion Range; fourth, the temperature of many of them is distinctly higher than the mean annual temperature of the region, which is not the case with springs fed from shallow and local sources. All these differences suggest a relation to the rock structure, and such a relation is further suggested by the somewhat linear arrangement of the different groups and by the evidences of recent faulting recorded by Mr. Gilbert near Hot Springs, Fish Springs, Willow Springs, Redding Springs, and Knoll Springs. As the tendency of the pools to become inclosed by a shelf or knoll seems to depend on the encircling vegetation, and as the luxuriance of this vegetation may result from the warmth of the water, it may be that the knolls are in this way genetically related to the rock structure.

## QUALITY OF GROUND WATER.

### SUBSTANCES CONTAINED IN WATER AND THEIR EFFECTS UPON ITS USE.

The water that falls as rain or snow contains little or no mineral matter, but when it enters the ground and percolates through the earth it gradually takes into solution substances with which it comes into contact. Therefore underground water always contains some dissolved mineral matter. As long as this matter is in solution it is invisible, but when the water evaporates, as in a teakettle or a steam boiler or on the surface of a low valley flat, the mineral matter is left behind and forms a crust or scale. Ground waters differ greatly in the total amount of substances contained in solution and also in the proportions of the different substances. The most common of these substances are calcium, magnesium, sodium, potassium, carbonates, bicarbonates, sulphates, and chlorine. When, by the evaporation of the water or some other process, these substances are thrown out of solution, they form compounds such as calcium carbonate (limestone), calcium sulphate (gypsum), sodium carbonate (black alkali), sodium sulphate (Glauber's salt), and sodium chloride (common salt).

Water will also take up organic matter with which it comes into contact, and this organic matter may contain myriads of bacteria that become suspended in the water.

The character of water and its value for various uses depends largely on the substances it contains in solution or suspension.

Small amounts of the common mineral constituents are not harmful to health. Chlorides are not objectionable in drinking water if only 50 to 100 parts per million are present, but amounts clearly perceptible to the taste render water unpalatable. Magnesic and sodic sulphated waters are laxative and very high magnesium or sodium content renders water unfit for man or beast. The worst form of alkali water is that which contains alkali carbonates.

Most of the bacteria that water may contain are probably harmless, but among them may be the germs that produce typhoid fever or other disease. Hence water that is known to contain a large number of bacteria or a large amount of organic matter is regarded with suspicion, and if some of the bacteria are of the kind that come from the intestines of man or other animals the water is considered unsafe for drinking and general household uses.

Calcium and magnesium render water hard and therefore poor for toilet and laundry uses. When water is boiled bicarbonates are decomposed and an equivalent amount of calcium and magnesium is removed, but the calcium and magnesium in excess of this amount, such as would be present in gypsiferous waters, can not be precipitated by boiling. Sodium and potassium do not consume soap and therefore do not make water hard.

Calcium and magnesium compounds are the principal constituents of the scale that forms in boilers. Sodium and potassium compounds do not form scale, but when they occur in large quantities they cause foaming and priming in boilers.

Among the common alkali salts, the least injurious to plants are the sulphates, the most injurious are the carbonates, and the chlorides occupy an intermediate position. Whether water of a certain quality can be successfully used for irrigation usually depends on a number of related conditions, among which may be mentioned the type of crop that is to be raised, the amount of alkali already in the soil, the natural drainage of the land or the ease with which artificial drainage could be established, and the cost and abundance of the water itself. If the land is poorly drained and water containing considerable quantities of alkali is applied sparingly, the evaporation of this water results in the gradual accumulation of alkali in the soil; but if the land is well drained and the same kind of water is applied in large quantities the alkali that would otherwise accumulate in the soil is washed out. T. H. Means[1] states that the limit of concentration for irrigation water has been placed by some authorities at 300 parts per million of sodium chloride (common salt) or sodium carbonate (black alkali) and at from 1,700 to 3,000 parts per million of the less harmful salts; that these limits are probably high enough

[1] The use of alkaline and saline waters for irrigation: U. S. Dept. Agr., Bur. Soils Circular 10.

where water is sparingly used, and that even then all except the most sandy soils or those with exceptionally good natural drainage would ultimately be damaged. But he describes certain gardens in Sahara Desert, in which vegetables considered sensitive to alkali are successfully irrigated with water that contains as much as 8,000 parts per million of soluble salts of which as much as one-half is sodium chloride. In these gardens a very thorough system of drainage was established and the water was applied frequently in large quantities.

### WATER FROM THE MOUNTAIN AREAS.

The mountain streams of western Utah are fed partly by springs and partly by the run-off from rain and melting snow. The water of these streams is, in general, moderately hard, but not otherwise highly mineralized, most of the dissolved solids probably being contributed by the springs. It is used chiefly for irrigation and is nearly everywhere good for this purpose.

The water derived from the Tertiary igneous rocks and overlying loose waste likewise generally contains only moderate amounts of dissolved solids, as is shown by the analyses given in the section on the Tintic mining district (p. 85).

### GROUND WATER IN THE VALLEYS.

The water in the beds of sand and gravel beneath the alluvial slopes does not differ greatly in its mineral content from that in the mountain streams, though on the average it is probably somewhat harder. In the central flats, where the soil contains considerable alkali, the water near the surface may be charged with sodium salts, but the deeper ground water is ordinarily of good quality. Most of the springs in low places also furnish good water, though some of them have deposited enough mineral matter to produce alkali flats.

### GROUND WATER IN THE DESERTS.

On the alluvial slopes bordering the large desert flats and near the base of these slopes the ground water is generally of good quality, being comparable to that in similar situations in the valleys. The flowing wells at Callao serve as an example. But in the interior of the desert areas much of the ground water is saline.

The mineral character of the ground water in the vicinity of Deseret is especially interesting. The water in the upper beds is so salty that it is not used, but the water in the deeper beds thus far encountered by the drill does not contain enough salt to make it objectionable for drinking and household use, though it contains more than is generally found in the water beneath the alluvial slopes. The water from most of the deeper beds contains hydrogen sulphide

gas, which imparts a characteristic odor and tends to come out of solution in small bubbles when the water is brought into contact with the air. This deeper water is softer than most of the water of the region.

Water is made hard by its content of calcium and magnesium, which are derived largely from calcium carbonate and magnesium carbonate. But these carbonates can be dissolved by the water only through the aid of carbon dioxide, and the carbon dioxide is supplied chiefly by decomposition of vegetable matter in the soil. It has been explained that the principal ground-water supply of the region comes from the high mountain areas, which have relatively heavy precipitation and abundant vegetation, but that the supply for the vicinity of Deseret comes in large part from the Lynn bench, which has only a scanty desert vegetation. It is possible that this difference in vegetation, resulting in a difference in the supply of carbon dioxide, may account for the deficiency of calcium and magnesium, and hence for the softness of the water. This hypothesis accords with the analysis given on page 116.

The wells on the flat of Sevier Desert that supply good water are all within a few miles of the margin of the Lynn Bench. Deep wells farther southwest yield highly mineralized water. Every water-bearing bed in the railroad wells at Goss and Neels, which are, respectively, 1,775 and 1,998 feet deep, yields salty water.

Similar conditions exist on the flat between Deep Creek and Fish Springs ranges. The wells at Callao yield good water, but in several wells drilled near Fish Springs Range only salty water has been discovered.

In Escalante Desert more satisfactory water has been found. The drilled wells at Lund and Beryl, Webster's flowing well, a large number of the dug wells, and the deep wells at Milford yield water of fairly good quality, but on the flat between Milford and Black Rock most of the deep wells yield salty water.[1]

### WATER FROM SPRINGS.

The character of the water from the mountain springs and the ordinary lowland seepage springs has already been discussed, but the character of the water from several less common types of springs requires special mention.

The Black Rock Springs and most of the other springs from lava beds yield water that is only moderately mineralized, but the water from Clear Lake contains considerable mineral matter, and that of the Hot Springs north of Abraham is very salty.

[1] Lee, W. T., Water resources of Beaver Valley, Utah: Water-Supply Paper U. S. Geol. Survey No. 217, 1908, p. 46.

With a few exceptions the pool and knoll springs in Snake and Fish Springs Valleys yield water that is good to the taste. The Hot Springs northeast of the Fish Springs Range and the Warm Spring near Hatton, like the Hot Springs north of Abraham, yield highly mineralized water.

## IRRIGATION WITH GROUND WATER.

### DEVELOPMENTS.

The total area at present irrigated with water from wells does not exceed a few hundred acres, and nearly all of this water comes from flowing wells. The most extensive developments have been made in Parowan Valley, and Juab Valley ranks second in this respect. Small tracts are irrigated with artesian water at Callao and in some other areas.

Pumping for irrigation has been attempted at the Desert Wells (north of Burtner), on the farm of Edgar Warton (west of Holden), and to a slight extent in Juab Valley and elsewhere. The Desert Wells and Warton projects have been abandoned and no specific data in regard to them were obtained.

At the Desert Wells the water rises to the surface, but pumps were installed, apparently for the purpose of supplying water in larger quantities and of lifting it to a little better land than that on which the wells are located. These wells are so small in diameter and so shallow that they probably did not yield very large quantities of water. Moreover, the soil is heavily charged with alkali (as is shown by the analysis given on p. 110) and the drainage is poor.

The farm of Edgar Warton is situated on the flat between Holden and Pavant Butte (Sugar Loaf Mountain), where the ground water is near the surface. Several wells of large diameter were here dug to a depth of 40 feet. The water was lifted first with windmills and later by means of a gasoline engine.

### PROSPECTS.

More land could be irrigated with artesian water if wells of larger diameter, tapping a greater number of water-bearing beds, were sunk, and if such wells were more widely distributed over the favorable districts. As the areas of flow do not extend far beyond the limits of the alkali flats only the outer zones are ordinarily available for agriculture, but in order to recover the largest amounts of water the wells should be widely distributed along these zones. It is also important to conserve the water by allowing it to flow only when it can be used.

At best, however, the amount of land that can be irrigated with flowing wells is small, the difficulty being that the head is everywhere so low that the yield is not large and trouble with alkali generally threatens where flows of consequence can be obtained. A short distance up the slope from the margin of a flowing area and at a slightly higher altitude the soil is generally better. Here the water in drilled wells will stand near the surface and a moderate pumping lift will suffice to raise comparatively large quantities to a position where it can be used for irrigation.

Irrigation by pumping from wells could probably, by wise management, be made successful in Juab, Round, Pavant, Parowan, Rush Lake, and Snake valleys, in parts of Escalante Desert, and on a smaller scale in other areas, such as Tintic Valley. In Sevier Desert, where trouble with alkali menaces, ground water might be successfully used for irrigation after an efficient system of artificial drainage has been installed. Possibly the water from the large pool springs could also be made available by pumping.

The principal factors that must be considered in pumping for irrigation are the quantity of water available, the quality of the water and of the soil, the cost of sinking the wells and installing the pumping plants, the cost of pumping, and the value of the crops.

### QUANTITY OF WATER.

The amount of available ground water in a given locality is frequently overestimated. Because the existing wells, which are required to furnish only the small supplies needed for domestic or live stock uses, have never shown signs of becoming exhausted, it should not be inferred that any number of wells pumped continuously at a rapid rate will likewise be inexhaustible. Ground water is limited in quantity just as surface water is limited, and heavy pumping will soon develop these limitations even where there was not the slightest indication of them before. The quantity of water that a stream will furnish can be estimated with considerable accuracy on the basis of a series of definite measurements, but no such precise methods can be employed to determine in advance the available quantity of ground water. For this reason projects based on ground-water supplies must be developed with great caution. It is true that ground-water supplies partake of the nature of huge reservoirs filled with water, but figure 5 and the accompanying discussion make it evident that only a small part of these large stores can be recovered without pumping from great depths, which would involve greater expense than can be afforded for ordinary irrigation projects. To be permanently successful a project must not draw from the underground reservoir at a rate much more rapid than that at which the supply is replenished by nature.

In order to obtain the maximum amount of ground water, it is necessary to distribute the wells over the largest area feasible. The amount of water that can be recovered in a given locality is sufficient to irrigate only a small part of the total available land, but the aggregate acreage that could be irrigated annually in these three counties with ground water is no doubt large enough to add substantially to their total agricultural production.

## QUALITY OF WATER AND SOIL.

Where water from a stream or spring can be led upon land by means of inexpensive gravity ditches, it may be profitable to use this supply even though the alkali in the water or soil interfere seriously with the crops; but where an expensive pumping plant is required and the water must be lifted by means of power that costs money good crops must be assured. If the cost of producing the crops exceeds their value when sold, the project must obviously come to disaster. Before a pumping plant is installed the water that is to be used and the soil to which it is to be applied should be analyzed, and if the results are not favorable the project should not be carried out. The cost of having the quality of the water and soil investigated is small as compared with the cost of installing and operating a pumping plant.

## COST OF PUMPING.

The cost of installation includes the cost of the wells, pumps, engine or other source of power, reservoir and distributing pipes or ditches, and the cost of preparing the land for irrigation.

Where irrigating is done on a small scale windmills can be successfully used, but the amount of water that they will lift is not great, and they are unreliable because they depend on the caprice of the wind. Where windmills are used reservoirs of considerable size should be constructed, and winter irrigation should as far as is feasible be practiced.[1]

For somewhat larger pumping plants gasoline engines furnish a convenient and rather inexpensive source of power. Nine pumping tests were made by Prof. C. S. Slichter in Arkansas Valley, in Kansas, in which gasoline engines ranging in size between 1½ and 10 horsepower were used. In these tests the cost of the gasoline ranged between 12½ and 22 cents per gallon; the total distance that the water was lifted ranged between 15 and 22 feet; and the cost of fuel for pumping one acre-foot of water ranged between $1.09 and $3.75.[2] Fourteen similar tests were made by the same investigator in Rio

[1] See Fuller, P. E., The use of windmills in irrigation in the semiarid West: Farmers' Bull. No. 394, U. S. Dept. Agr., 1910.

[2] Slichter, C. S., The underflow in Arkansas Valley, in western Kansas: Water-Supply Paper U. S. Geol. Survey No. 153, 1906, pp. 55, 56.

Grande valley with gasoline engines ranging between 5 and 28 horsepower. The cost of the gasoline here ranged between 14 and 17 cents per gallon; the total lift ranged between 24 and 46 feet; the cost of fuel for pumping one acre-foot ranged between $1.04 and $5.80; and the total cost for pumping one acre-foot, including labor, interest on investment, and depreciation, ranged, according to the estimates, between $2.21 and $13.20.[1] It should be understood that the total lift is considerably greater than the normal depth to water because the water level is inevitably lowered as soon as pumping is begun, and also because it is generally necessary to lift the water a few feet above the surface. In a well in which the water level is normally 20 feet below the surface the water may readily be lowered to a level of 30 or 40 feet below the surface when a large pump is operated.[2].

In a discussion of the cost of pumping in Arkansas Valley the following statement is made by Prof. Slichter in regard to gas-producer plants: [3]

If plants of from 20 to 50 horsepower are constructed, as I believe will inevitably be the case in the near future, the cheapest power will probably be found in the use of coal in small gas-producer plants in connection with gas engines. These small gas-producer plants are largely automatic in action and can be operated by anyone. With hard coal or coke or charcoal at $8 per ton, the cost of power would be less than one-half cent per horsepower for one hour, or only one-fifth of the cost of power from gasoline at 22 cents a gallon. The writer anticipates no difficulty, therefore, in keeping the cost of water below 60 to 75 cents an acre-foot for fuel, or below $1.25 to $1.50 an acre-foot for total expenses. Hundreds of such plants have been put in use in England during the past ten or more years, and they are in charge of unskilled labor. These gas-producer plants are used in England for a great variety of purposes, such as power for agricultural machinery and for small electric-light plants for country estates, etc. They are used in as small units as 5 horsepower.

In this country the producer-gas plants have been in use for several years, and at the present moment they are fast taking the place of steam power in new plants. The cost of a producer plant and gas engine is about the same as the cost of a steam engine and boiler of the same size if everything is included, but the cost of power from the producer-gas plant is very much less than that obtained from small steam engines.

In producer plants, ranging upward from 100 horsepower, a style of plant may be installed in which soft coal or lignite may be successfully used. This still further cuts down the cost of power. In fact, large plants of this type furnish the cheapest artificial power that has yet been devised. The saving is not only in fuel, but also in labor, as one man is capable of running a 300-horsepower plant.

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[1] Slichter, C. S., Observations on the ground waters of Rio Grande valley: Water-Supply Paper U. S. Geol. Survey No. 141, 1905, pp. 34, 35.

[2] For further information on pumping plants see Gregory, W. B., The selection and installation of machinery for small pumping plants: U. S. Dept. Agr. Exper. Sta. Circular 101, 1910.

[3] Slichter, C. S., The underflow in Arkansas Valley, in western Kansas: Water-Supply Paper U. S. Geol. Survey No. 153, 1906, pp. 57, 58.

Coal that could be used for generating power exists in the mountains of eastern Iron County.[1]

The mountain streams of this region are not large, but have so much fall that they could be used to develop considerable power which could be transmitted by means of electric currents and used for pumping ground water. Several small power plants, used chiefly for electric lighting, have already been installed.

## VALUE OF CROPS.

The staple crops of this region are wheat and alfalfa. If more intensive crops, yielding larger returns per acre, could be raised, the cost of pumping could be better afforded, but it is not safe to base calculations on such crops unless it has been established that they can be successfully produced and that there will be a permanent demand for them in the market. As cold air is heavy and therefore tends to sink, the low parts of the valleys and deserts have colder nights than the alluvial slopes or bench lands, and are more liable to have late and early frosts. For this reason fruit raising is not very successful at the lower levels where the ground water is near enough to the surface to be pumped.

The best use of the ground water is probably to supplement the streams, especially since the flow of the latter is very irregular and their water can not easily be stored. In the spring and at other times when the streams are swollen the surplus water, now largely lost, can be applied to fields on the lower parts of the slopes. When, later in the season, the streams are small and none of their water will reach these fields, the growing crops can be irrigated by pumping from wells. By this combination method the ground water, available at the times when most needed, but used only when necessary, will have more than ordinary value, and small amounts will suffice to reclaim relatively large tracts of desert land.

## CULINARY WATER SUPPLIES.

Most of the settlements that depend on mountain streams for their irrigation supplies are situated so far up the alluvial slopes that wells can not easily be obtained. Naturally the water for drinking and household use was at first also derived from these streams, and in most places it was drawn from open ditches constructed along the streets. Water from the streams is now generally regarded as unsatisfactory, though it is still used by most of these communities. The domestic animals kept in the settlements roil the water and make it filthy, the flocks of sheep that graze in the mountains impart to it

[1] Lee, W. T., The Iron County coal field, Utah: Bull. U. S. Geol. Survey No. 316, 1906, pp. 359–375. Richardson, G. B., The Harmony, Colob, and Kanab coal fields: Bull. U. S. Geol. Survey No. 341, pp. 379–401.

their characteristic odor, and the heavy rains that occasionally fall in the mountains make it muddy.

The principal danger to health, however, probably does not lie in the pollution from these obvious causes, but in that which results when persons in the mountains become sick with diseases whose germs can be carried by water. It has been demonstrated that in a community using water from a stream an epidemic of typhoid fever can be produced by a single patient suffering with this disease at some point in the drainage basin of the stream. In some localities in this region there have been epidemics of typhoid fever and other enteric diseases, and isolated cases occur after the epidemics are checked. If a person in the mountains is attacked with typhoid fever he is generally ill for some time before he is brought to a settlement and placed in care of a physician. While he is in the mountains his excreta, burdened with typhoid germs, are usually not disinfected and can easily be washed into a stream that furnishes the drinking supply for a settlement below. This disease is no doubt spread by other agencies, a discussion of which is not within the province of this paper, but there is evidence that pollution of the water supplies is an important cause of its prevalence.

Spring waters sufficient for a public supply and high enough to be led by gravity through pipe lines are found within a few miles of nearly every village situated on an alluvial slope. Waterworks supplied from springs have already been installed at Nephi and Holden and are being planned for Cedar City, Fillmore, and other towns. In most places the expense of installing such a system of waterworks is heavy when compared with the financial resources of the community, but its value in furnishing a convenient, clear, and wholesome supply of water would be great. In general the plans that are being considered do not provide for fire protection, which would involve an additional cost for a reservoir and large mains leading from it. Springs used for public supplies should of course be carefully guarded against contamination of any sort.

Several of the settlements, such as Scipio, Meadow, and Hatton, are situated on relatively low ground, where water is found by digging to moderate depths. Here open wells furnish most of the supplies for drinking and household uses. Their water may be contaminated by privies near the wells or by other sources of pollution, but it is generally less dangerous to health than the stream water. Safer supplies could be obtained by drilling to deeper water-bearing beds of sand or gravel and finishing the drilled wells with tight iron casings to shut out the surface pollution.

In the settlements along Sevier River nearly the entire domestic supply is obtained from wells. Most of these wells consist of small drilled holes with iron casings 2 inches or less in diameter. Where

the casing extends to the surface and the water overflows there is little or no chance of pollution. Where the water remains some distance below the surface, as at Abraham and Burtner, but is allowed to discharge into a dug pit, there is more chance for pollution unless the pit is made water-tight. Where the casing is large enough and the water is yielded rapidly enough the danger of pollution can be diminished by extending the casing to the surface and pumping from inside of it. At Leamington there are shallow dug wells, but water from Sevier River is also used. The water in the dug wells is liable to be somewhat polluted, but it is less dangerous to health than the river water. The latter should not be used for drinking.

At Silver City, Robinson, and Mammoth the water supplies are brought through pipe lines from distant mountain springs, and with ordinary precautions they ought to be pure and wholesome. The supplies for Eureka are in part conveyed through pipe lines from shallow wells in the Homansville Basin and in part drawn from shallow private wells in the city. Many of the private wells are so situated that they are dangerously exposed to pollution. With proper care the Homansville water can be protected, but contaminating agencies, such as slaughterhouses, should not be tolerated in this basin.

## SUPPLIES FOR DRY FARMS.

On the dry farms water is required for culinary purposes and for the horses and traction engines used in tilling the soil and harvesting the crops. Many of these farms have been established high up on the alluvial slopes or on other so-called bench lands, where large tracts of fertile soil, free from alkali, have hitherto remained unused. Many of these elevated tracts are without water supplies and the water used on the dry farms is hauled long distances.

The rainfall data indicate that most of the region considered is too arid for agriculture without irrigation and that dry farming will be restricted practically to the eastern valleys. As these valleys have comparatively abundant rainfall and most of them receive mountain streams their ground-water prospects are comparatively good. It seems probable that in most localities where dry farming is practiced adequate supplies of fairly good water can be procured from wells within convenient distances of the fields that are cultivated.

Where the unconsolidated sediments are known to be saturated to the level of the low areas, such as Juab, Little, Round, Pavant, Parowan, Rush Lake, and Tintic valleys, water can generally be obtained by sinking wells higher up on the bench lands than has thus far been done, but the holes must be put down to depths of several hundred feet, and the water will have to be lifted from considerable depths beneath the surface. Positions not too high and as far as possible from the margins of the mountains, or from any outcropping

rocks, should be selected for wells, otherwise the water may be reached at depths from which it can not be conveniently lifted, or barren bed rock may be struck before any water is found.

Prospecting for wells in these localities can be done better with drilling machines than by digging. The type of drill best adapted for this kind of work is discussed on page 59. By ascertaining the difference in altitude between the point where the drilling is to be done and the nearest successful well in the valley, some conception can be obtained of the probable depth to water. Generally, drilling should not be undertaken where this difference is more than several hundred feet.

If casing not less than 4 inches in diameter is used, there will be no special difficulty in lifting enough water for dry-farm purposes from depths of 200 to 300 feet, or even more. A deep-well pump should be used which is entirely independent of the casing and whose cylinder and valves are near the bottom of the well. The pump rod will occasionally break, because it will unavoidably wear against the inside of the pump pipe. On account of the high lift the valves must be kept in good condition. Repairing the pump rod or valves in a deep well involves no great expense, but generally requires the labor of several men for a few hours.

Certain arable tracts, such as lie between Juab and Tintic valleys and in the region southwest of Kanosh, are so elevated and in many places appear to have rock so near the surface that it is doubtful whether available water exists there in the unconsolidated sediments, while drilling into rock is an expensive and uncertain undertaking.

In Tintic Valley the alluvial slopes are so high and so much dissected that only the lower parts of these slopes have good prospects.

On most of the Lynn bench the conditions are favorable for obtaining satisfactory wells by sinking to moderate depths.

## SUPPLIES FOR THE RANGE.

In the extensive tracts which are too arid for agriculture of any kind, but which have a certain value for grazing, water supplies are needed for live stock, but so great is the aridity that watering places are scarce and even small supplies of poor water are highly prized. Parts of the region are so far from any supply that they can be used for grazing only in winter when there is snow on the ground.

The prospects of getting wells are of course much poorer here than in the less arid dry-farming districts. In upland areas, such as the country lying between Sevier Lake and Snake Valley or the extensive bench lands east of the Confusion and House ranges and west of the Thomas and Fish Springs ranges, the chances are strongly against finding ground water.

Wells that would furnish valuable supplies for live stock, however, would probably be successful in certain localities now destitute of water supplies. Such localities exist in Sevier Desert north of the Desert Wells, in the Old River Bed region, in the low parts of White Valley, and possibly in the bottoms adjacent to Sevier Lake and the lowest part of Wah Wah Valley. Wells should not be located either far up on the slopes or far out on the flats, but on intermediate low ground near the base of the slopes. The larger, steeper, and more gravelly the slope or bench and the more extensive the drainage area that pours its freshets over it, the better the chances of obtaining water. In these localities rather thorough explorations for ground water can be made without expensive drilling, for the formations encountered will almost invariably consist of unconsolidated sediments that are not difficult to penetrate, and if bedrock should be struck it would probably be unwise to drill into it. Moreover, if properly located, a hole a few hundred feet deep will give a fair test.

Iron County is better supplied with watering places than Juab and Millard counties, and this fact gives it a distinct advantage in raising live stock. The small springs in the western mountains are utilized and a number of stock wells have been sunk in different parts of Escalante Desert. The value of these wells is great in comparison with their cost.

## BOILER SUPPLIES.

As this region contains no manufacturing towns, boiler supplies are not of primary importance, but such supplies are needed for the traction engines on the dry farms, for the stationary engines at the mines, and for the locomotives on the railroads.

In endeavoring to procure locomotive supplies of adequate quantity and satisfactory quality at proper intervals along the San Pedro, Los Angeles & Salt Lake Railroad many difficulties were encountered. On the main line supplies are now provided at Tintic Junction and Jericho (in Juab County), at Lynn, Oasis, Goss, and Black Rock (in Millard County), and at Lund, Beryl, and Modena (in Iron County). At Tintic Junction the supply is taken from the Cherry Creek pipe line; at Jericho it comes through small pipes from a number of springs from 3 to 4½ miles distant; at Lynn it is drawn from a well that furnishes a large amount of good water; at Oasis it is also obtained from a well, but the water is less desirable for boiler use than that at Lynn; at Black Rock a supply of good water is derived from the springs near the station; at Lund and Beryl the supply is obtained from wells that furnish water of satisfactory quality; and at Modena the supply is obtained through a pipe line from springs or wells a short distance from the station.

The greatest difficulty was experienced between Oasis and Black Rock. An old well at Clear Lake and the more recently drilled wells

at Neels and Goss all yielded highly mineralized water. The wells at Clear Lake and Neels have been abandoned, but the water from the Goss well is used in locomotives when necessary, although it is salty.

In addition to being used in locomotives, the railroad supplies are largely relied upon for domestic purposes by the people who live at the stations, there being no other water at several of the inhabited points. At Clear Lake the drinking and culinary supplies are taken from a reservoir into which water is hauled by the railroad company.

On the branch line of the San Pedro, Los Angeles & Salt Lake Railroad that passes through Juab Valley good locomotive supplies are obtained from a flowing well at Starr and a spring near Juab.

The Rio Grande Western Railroad Co. has a locomotive supply at Eureka, the water being derived from shallow wells.

## CONSTRUCTION OF WELLS.

### TYPES OF WELLS IN USE.

Four kinds of wells are found in this region: (1) Ordinary dug wells; (2) small cased wells; (3) large drilled wells; and (4) large open wells with infiltration galleries.

The dug wells, which are the most common type, are found on the flats and on the lower parts of the alluvial slopes. They are sunk only a few feet below the level at which water is struck and are rarely more than 100 feet deep. Their construction requires considerable labor but costs little otherwise for they are seldom curbed above the water level and the water is generally drawn with a bucket attached to a rope.

The small cased wells are found in the flowing areas and in parts of Sevier Desert where flows are not obtained but where the shallow ground water is salty while the deeper water is of good quality. They are sunk where it is desirable to shut out the first water encountered and to tap deeper horizons—either because the deeper water is under greater pressure or is of better quality. The casing, which consists of iron pipe, is ordinarily between 1 and 2 inches in diameter. Since these wells are sunk only in the low areas where the sediments penetrated consist of clay and sand with rarely any bowlders or large gravel, they can be drilled rapidly by the jetting or hydraulic process with a light and inexpensive rig. Where the water does not rise to the surface by artesian pressure it is customary to have a so-called "pit flow," a hole being dug to such a depth that the water from the deep stratum, coming up through the casing, will overflow into the hole, from which it is brought to the surface by a pump or other lifting device.

A number of deep wells of larger diameter have also been drilled. Some of these were put down by the railroad company; others were test wells sunk by the State of Utah; and still others were oil prospects sunk by different concerns.

The large dug wells with tunnels or infiltration galleries are a special type adapted to special conditions. They are found chiefly at Eureka and Homansville where it is important to obtain as large supplies as possible from the meager seepage out of the decomposed igneous rock and overlying loose waste.

### DRILLED WELLS ON ALLUVIAL SLOPES.

The wells on the alluvial slopes are, almost without exception, of the dug type, but in some respects drilled wells with iron casing 4 to 6 inches in diameter would be better adapted to the conditions. They could easily be sunk to greater depths than the dug wells and thus they would frequently find water where the dug wells are failures. They would not, like the dug wells, end in the first water-bearing bed encountered, which is generally weak, but could be carried to deeper horizons where large supplies would be found. They would also be better protected from pollution and would therefore furnish cleaner and safer water for drinking and culinary use. If the labor required in digging a well is not considered, a dug well is, of course, much less expensive than a drilled one would be, but if the labor were paid for at a fair wage the dug well would probably not be cheaper. Since the digging is frequently done at times when there is no other work, the actual cost of many of the dug wells is not great. For drilling on the bench lands the light jetting rigs used on the flats would not be adequate, but heavy rigs, such as are used in sinking oil wells, are not necessary. A portable rig with cable and 4-inch or 6-inch percussion drill, built to go to depths of several hundred feet, will be serviceable for this kind of work. Such a machine can be purchased at a moderate price and operated with only moderate expense. If bowlders too large to be pushed aside by the drill are struck it may be possible to shatter them by the use of explosives, or, if the drilling has not progressed far, a new hole can be started with no great loss of time.

### "PIT FLOWS."

In the so-called "pit-flow" wells, the pit must be dug to the surficial ground-water level or somewhat lower. Unless these pits are made water-tight by means of cement curbs, they may admit salty water that in some places occurs near the surface, or bacteria-laden organic matter from nearby privies or other sources of pollution. The iron casing that extends to the deeper water is in most wells of

so small diameter that a pump placed inside of it would not give satisfactory service, but if wells with somewhat larger casing (perhaps 4 inches in diameter) were made, the casing could be brought to the surface and a pump hung inside of it, thus dispensing with the pit. Where the water level is at a considerable distance below the surface these wells of larger diameter would probably not be more expensive than the small wells when the cost of the cement curb for the pit is included.

### IRRIGATION WELLS.

Wherever irrigation with ground water is undertaken wells of large diameter should be drilled. These wells should be drilled deep enough into the unconsolidated sediments to tap water-bearing beds that have not been reached in ordinary drilling, and they should admit water at as many levels as practicable. Since in the localities where the ground water is near the surface the unconsolidated sediments are easily penetrated with a drill, and since rock drilling is not involved, the difficulty of making these larger irrigation wells will not be as great as might be supposed. With the proper type of machine and with some experience in operating it, the work can be done rapidly and with few mishaps. The adoption of better methods than now prevail will lead to lower costs and to larger yields from both flowing and pumped wells, and may make practicable the development of ground waters in areas where their development is now impracticable.

### THE CALIFORNIA OR "STOVEPIPE" METHOD OF WELL CONSTRUCTION.

In California, where irrigation water is very extensively drawn from unconsolidated valley-fill material similar to that in which most of the valuable Utah ground waters occur, a special type of well has been evolved. In the belief that the California method of well construction can be used with advantage in the valleys of Utah, the following description is quoted from a paper by Charles S. Slichter:[1]

#### CONDITIONS IN CALIFORNIA.

The valleys in southern California are filled with deposits of mountain débris, gravels, sands, bowlders, clays, etc., to a depth of several hundred feet, into which a considerable part of the run-off of the mountains sinks. The development of irrigation upon these valleys soon became so extensive that it was necessary to supplement more and more the perennial flow of the canyon streams by ground water drawn from wells in the gravels. This necessity was greatly accentuated by a series of dry years, so that ground waters became a most valuable source of auxiliary supply for irrigation in the important citrus areas in southern California. The type of well that came to the front and

[1] The California or "stovepipe" method of well construction: Water-Supply Paper U. S. Geol. Survey No. 110, 1905, pp. 32–36.

developed under these circumstances is locally known as the "stovepipe" well. It seems to suit admirably the conditions prevailing in southern California. In procuring water for irrigation the item of cost is, of course, much more strongly emphasized than in obtaining water for municipal use. The drillers of wells in California were not only confronted with a material which is almost everywhere full of bowlders and similar mountain débris, but also by a high cost of labor and of well casings. It was undoubtedly these difficulties that led to the very general adoption in California of the "stovepipe" well.

### DESCRIPTION OF APPARATUS AND METHODS.

The wells are put down in the gravel and bowlder mountain outwash or other unconsolidated material to any of the depths common in other localities. One string of casing in favorable location has been put down over 1,300 feet. The usual sizes of casings are 7, 10, 12, and 14 inches, or even larger. A common size is 12 inches. The well casing consists of, first, a riveted sheet-steel "starter," from 15 to 25 feet long, made of two or three thicknesses of No. 10 sheet steel, with a forged steel shoe at lower end. In ground where large bowlders are encountered these starters are made heavier, the shoe 1 inch thick and 12 inches deep, and three-ply instead of two-ply No. 10 sheet-steel body.

The rest of the well casing, above the starter, consists of two thicknesses of No. 12 sheet steel made into riveted lengths, each 2 feet long. One set of sections is made just enough smaller than the other to permit them to telescope together. Each outside section overlaps the inside section 1 foot, so that a smooth surface results both outside and inside of the well when the casing is in place, and so that the break in the joint is always opposite the middle of a 2-foot length. It is these short overlapping sections which are popularly known as "stovepiping."

The casing is sunk by large steam machinery of the usual oil-well type, but with certain very important modifications. In ordinary material the "sand pump" or "sand bucket" is relied upon to loosen and remove the material from the inside of the casing. The casing itself is forced down, length by length, by hydraulic jacks, buried in the ground, and anchored to two timbers 14 by 14 inches and 16 feet long, which are planked over and buried in 9 or 10 feet of soil. These jacks press upon the upper sections of the stovepiping by means of a suitable head. The driller, who stands at the front of the rig, has complete control of the engine, the hydraulic pump, and the valves by which pistons are moved up or down, and also of the lever that controls the two clutches which cause tools to work up and down or to be hoisted.

The sand pumps used are usually large and heavy. For 12-inch work they vary in length from 12 to 16 feet, are 10⅝ inches in diameter, and weigh, with lower half of jars, from 1,100 to 1,400 pounds.

After the well has been forced to the required depth, a cutting knife is lowered into the well and vertical slits are cut in the casing where desired. A record of material encountered in digging the well is kept and the perforations are made opposite such water-bearing materials as may be most advantageously drawn upon. A well 500 feet deep may have 400 feet of screen if circumstances justify it.

The perforator (see fig. 6) for slitting stovepipe casing is handled with 3-inch standard pipe with ¾-inch standard pipe on the inside. In going down or in coming out of the well the weight of the ¾-inch line holds the point of the knife up. When ready to "stick" the ¾-inch line is raised. By raising slowly on the 3-inch line with hydraulic jacks, cuts are made from three-

eighths to three-fourths inch wide and from 6 to 12 inches long, according to the material at that particular depth. In another type of perforating apparatus (fig. 7) a revolving cutter punches fine holes at each revolution of the wheel. This style of perforator is called a "rolling knife." Besides these many other kinds of perforators are in use in California. In fact, the perforator is a favorite hobby of the local inventors. They all seem to work well.

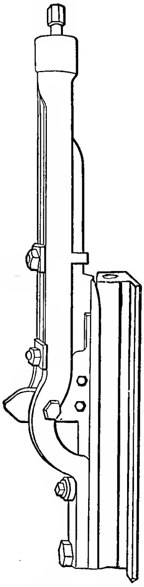

FIGURE 6.—Perforator for slitting stovepipe casing.

### ADVANTAGES OF CALIFORNIA METHOD.

The advantages of this method of well construction are quite obvious. For wells in unconsolidated material, the California type is undoubtedly the best yet devised. * * *

Among the special advantages in the stovepipe construction we may enumerate the following:

1. The absence of screw joints liable to break and give out.
2. The flush outer surface of the casing, without couplings to catch on bowlders or to hang in clay.
3. The elastic character of the casing, permitting it to adjust itself in direction and otherwise to dangerous stresses, to obstacles, etc.
4. The absence of screen or perforation in any part of the casing when first put down, permitting the easy use of sand pump and the penetration of quicksand, etc., without loss of well.
5. The cheapness of large-size casings, because made of riveted sheet steel.
6. The advantage of short sections, permitting use of hydraulic jacks in forcing casing through the ground.
7. The ability to perforate the casing at any level at pleasure is a decided advantage over other construction. Deep wells with much screen may thus be heavily drawn upon with little loss of suction head.
8. The character of the perforations made by the cutting knife are the best possible for the delivery of water and avoidance of clogging. The large side of the perforation is inward, so that the casing is not likely to clog with silt and débris.
9. The large size of casing possible in this system permits a well to be put down in bowlder wash where a common well could not possibly be driven.

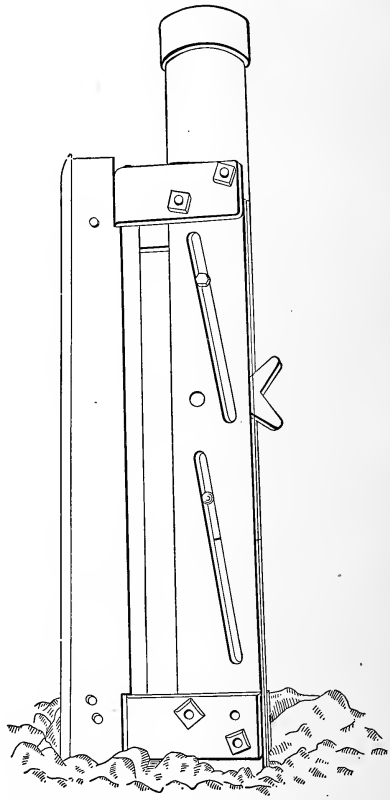

FIGURE 7.—Roller type of perforator.

10. The uniform pressure produced by the hydraulic jacks is a great advantage in safety and in convenience and speed over any system relying upon driving the casing by a weight or ram.

11. The cost of construction is kept at a minimum by the limited amount of labor required to man the rig, as well as by the good rate of progress possible in what would be considered in many places impossible material to drive in, and by the cheap form of casing.

### COST OF THE WELLS.

An idea of the cost of constructing these wells can best be given by quoting actual prices on some recent construction in California. According to contracts recently let near Los Angeles, the cost of 12-inch wells was:

Fifty cents per foot for the first 100 feet, and 25 cents additional per foot for each succeeding 50 feet, casing to be furnished by the well owner. This makes the cost of a 500-foot well $700 in addition to casing. The usual type of No. 12 gauge, double stovepipe casing, is about $1.05 a foot, with $40 for 12-foot starter with ¾-inch by 8-inch steel ring. A good driller gets $5 a day; helpers, $2.50 a day. The cost of drilling runs higher than that given above in localities where large and numerous bowlders are encountered.

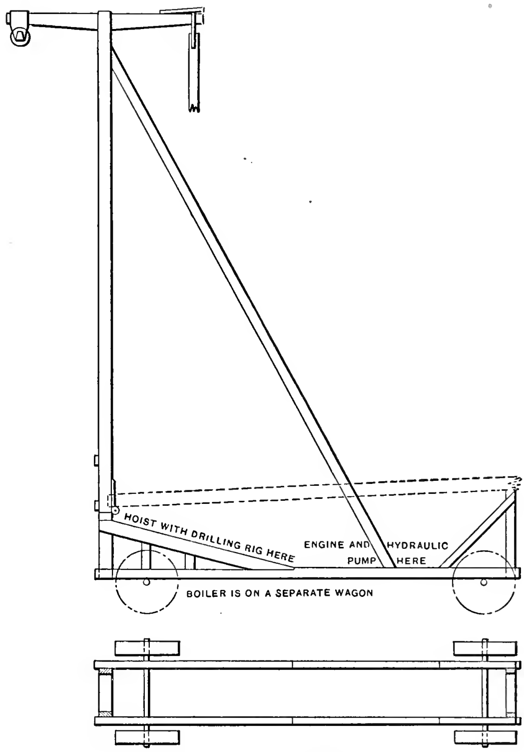


FIGURE 8.—Common form of California well rig.

The drillers build their own rigs according to their own ideas, so that no two rigs are exactly alike; that is, the drillers pick out the castings and working parts and mount them according to ideas that experience has taught them are the best for the wash formations in which they must work. Figure 8 shows a common form of rig.

It is not very profitable to name individual wells of this type and give their flow or yield, since conditions vary so much from place to place. From the method of construction it must be evident that this type of well is designed to give the very maximum yield, as every water-bearing stratum may be drawn upon. The yield from a number of wells in California of average depth of about 250 feet, pumped by centrifugal pumps, varied from about 25 to 150 miners' inches, or from 300,000 to 2,000,000 gallons a day. These are actual measured yields of water supplied for irrigation.

Among the very best flowing wells in southern California are those near Long Beach. The Boughton well, the Bixby wells, and the wells of the Sea

Side Water Co. are 12-inch wells, varying in depth from 500 to 700 feet and flowing about 250 miners' inches each, or over 3,000,000 gallons per 24 hours. The flow of one of these wells is the greatest I have seen reported. Among the records for depth are those of 1,360 feet for a 10-inch well, and 915 feet for a 12-inch well. A new 14-inch well has already reached a depth of 704 feet.

## WATERING PLACES ON ROUTES OF TRAVEL.

The following information is given for the benefit of persons who are strangers to this region but who wish for any reason to make a journey to some part of it. In connection with these directions, Plates I, II, and IV should be consulted. It should be remembered that changes are made from time to time and that wells in use at one time may later become filled up. For this reason inquiries should be made from local sources before starting on a trip.

### RAILWAY STATIONS AND THEIR CONNECTIONS.

On the maps of this region stations are indicated at intervals of several miles along the railroad, but most of these stations are merely switches, with no inhabitants and no shelter, food, or water.

Eureka, Robinson, and Silver City are mining towns where conveyances and provisions for a journey can be procured. Mona, Nephi, Juab, and Leamington are villages situated on the branch railroad that joins the main line at Lynn. Juab is the supply station for Levan and also has stage connections with Scipio. Leamington is a convenient station from which to reach Oak City. Lynn is a small railroad town where it may not be possible to outfit for a journey.

South of Lynn the inhabited stations on the main line which supply the region east and west are Akin (Burtner), Oasis, Clear Lake, and Black Rock, in Millard County; Milford, in Beaver County; Lund and Modena, in Iron County.

Oasis is the principal supply station for middle and lower Snake Valley, and is a good outfitting point for a journey to the western parts of Juab and Millard counties. Oak City and Holden can also be reached from this station. A stage goes twice each week to Joy and freighters make regular trips to Fish Springs.

Clear Lake is the principal supply station for Pavant Valley. A stage goes daily to Fillmore, whence there are stage connections with Meadow and Kanosh, and also with Holden and Scipio.

Milford is a mining town and also the supply station for Beaver and the other settlements of eastern Beaver County. From this point a branch railroad goes to Frisco and Newhouse, both of which are mining towns. From Newhouse there is a stage line to Garrison, in Snake Valley.

Lund is the supply station for Rush Lake and Parowan valleys. A stage runs daily to Cedar City, from which there are stage connec-

tions with the other settlements in these valleys, and indirectly with Sevier Valley. A halfway house between Lund and Cedar City is situated at Iron Springs.

Modena is the supply station for settlements in Washington County and for Gold Spring, Stateline, and Fay—small mining camps northwest of Modena. There are stage connections in both directions.

### TINTIC MINING DISTRICT TO SEVIER DESERT AND JOY.

The road leading from the Tintic district south to Leamington or Lynn runs near the central axis of Tintic Valley. A good watering place along this road is McIntyre's ranch, in the center of the valley and a short distance west of McIntire station. Water can perhaps also be procured at Jericho station or at some other point in the valley.

In going to Joy or points beyond, water can be obtained along Cherry Creek, preferably at Rockwell's ranch (NE. ¼ sec. 30, T. 12 S., R. 5 W.). The only permanent water supply between Rockwell's and Joy is at the Hot Springs, which are reached by leaving the main road and following a road that leads southward along the east side of the lava plateau. Since the water from these springs is too highly mineralized to be fit for man to drink, it is usually wisest to drive directly to Joy.

From Rockwell's, a road leads to Abraham and another to Oasis. Along the first there is no water until near Abraham; the second passes the Desert wells, where water can be procured.

### OASIS TO JOY, FISH SPRINGS, AND DEEP CREEK.

The trip from Oasis to Deep Creek is best made by way of Joy, Fish Springs, and Callao, but it can be made also by way of Antelope Spring, Trout Creek, and Callao.

Joy can be reached by way of Abraham or by way of the Old Smelter well and the road between Drum and Little Drum Mountains. On the Abraham route plenty of good wells are found between Oasis and Abraham, but the last watering place before reaching Joy is a well a short distance northwest of Abraham, at the buildings on the farm of Peter Christensen (SW. ¼ SE. ¼ sec. 15, T. 16 S., R. 8 W.). On the other route the Old Smelter well, 15 miles northwest of Deseret, is used by the freighters, but it can not be relied upon for a water supply unless specific information to that effect is obtained. The next watering place after leaving the Old Smelter well is at Joy, where there are two wells.

In going from Joy to Fish Springs the road shown in Plate IV is followed. The first watering place after leaving Joy is at Cane

Spring, which furnishes water of poor quality that is used, however, by the freighters for their horses. Six or seven miles farther north is Thomas's ranch, where there is plenty of good water. At the Utah mine, on the west slope of the Fish Springs Range, water elevated from the mine is used for both man and beast.

Between the Utah mine and Callao there is no water, but at the latter point there are good wells and springs. From Callao a road leads northward and westward across the mountains to the settlement in the valley of Deep Creek.

From the Utah mine or Callao the middle and upper parts of Snake Valley can be reached by way of Trout Creek, where there are two ranches with a good water supply. There is no dependable watering place between these points and Trout Creek.

### STAGE ROUTE TO FISH SPRINGS AND DEEP CREEK.

A stage goes from Ajax, in Tooele County, to Dugway, Thomas's ranch, the Utah mine, Callao, and Deep Creek, but this route has few watering places. Dugway (between the Dugway and Thomas ranges) is uninhabited most of the time and has no reliable water supply.

### OASIS TO SNAKE VALLEY.

The middle part of Snake Valley is most conveniently reached from Oasis, the road leading west across the House Range, White Valley, and the Confusion Range, as shown in Plate IV. After leaving the settlements the first watering place is Antelope Spring, on the House Range, and the second is one of the springs in White Valley. In White Valley the road forks, one branch leading to Trout Creek, another to Foote's ranch, and another to Meecham's ranch and Garrison. The first watering places reached on these routes after leaving the springs of White Valley are, respectively, at Trout Creek, Bishop's Springs (near Foote's ranch), and Knoll Springs. In Snake Valley, from Trout Creek to Garrison, Burbank, and Big Springs, watering places exist at no great distances apart.

### NEWHOUSE TO SNAKE VALLEY.

Newhouse is a mining town in Beaver County, at the terminus of a branch railroad that extends west from Milford. (Figs. 1 and 2.) From this point a stage is run west-northwest to Burbank and Garrison. On the route followed by the stage water can usually be procured at Kelley's, which is on the west side of Wah Wah Valley, opposite Newhouse. A short distance south of Kelley's are the Wah Wah Springs, the water from which is conveyed through a pipe line to Newhouse. Between Kelley's and Burbank there is no watering place.

#### BLACK ROCK AND CLEAR LAKE TO SNAKE VALLEY AND IBEX.

Snake Valley is more easily reached from Oasis or Newhouse than from Black Rock or Clear Lake. In making the trip from Black Rock it is best to go first to Newhouse or Kelley's and thence follow the stage road to Burbank. There is no watering place between Black Rock and Newhouse or Kelley's.

Ibex, a winter supply station for sheep herders, is situated a few miles west of the southern extremity of White Valley, about 35 miles by wagon road from Black Rock and 50 miles from Clear Lake. It is on unsurveyed land in T. 22 S., R. 14 W., and, as nearly as was ascertained, its location in this township is about midway between the north and south lines and a little over a mile from the west boundary. The water supply, which consists of rain or melted snow stored in small rock reservoirs, is not permanent and should not be depended on unless specific and reliable information is received in regard to it before the journey is undertaken. There is no water between Black Rock and Ibex. In going from Clear Lake to Ibex, water can be procured at the flowing well on the Swan Lake farm (6 miles from Clear Lake station) and also at the headquarters of the farm (on the banks of Sevier River, about 10 miles from the station). There is no water between the river and Ibex, and none between Ibex and Garrison.

## JUAB VALLEY.

### TOPOGRAPHY AND GEOLOGY.

Juab Valley is bounded on the east by a precipitous and imposing rock wall, formed in the northern part by the southernmost extension of the Wasatch Mountains and farther south by the San Pitch Mountains. (See Pl. I.) This section of the Wasatch Mountains is in the main a huge anticlinal fold, flanked on the west by steeply dipping strata, chiefly Carboniferous limestone.[1] It culminates in Mount Nebo, which projects to an elevation of 11,887 feet above the sea and towers 7,000 feet above the center of the valley less than 5 miles distant. The San Pitch Mountains contain younger formations and are capped by early Tertiary strata.

On the west the valley is bordered by a low but continuous range, back of which lie loftier mountain masses. This range consists of Paleozoic limestones, overlain to the north by igneous rocks and to the south by a series consisting chiefly of red and yellow conglomerate and sandstone, probably early Tertiary in age. This series dips steeply eastward and pitches toward the south.

The valley constitutes a structural trough continuous, in a sense, with Sevier Valley to the south and Utah Valley to the north, from

[1] Emmons, S. F., U. S. Geol. Survey, 40th Par., vol. 2, 1877, pp. 343, 344.

each of which it is separated by a low débris-covered divide. It is filled to an unknown depth with material washed from the mountain borders. It contains a north basin and a south basin, which are separated from each other by a broad, gentle elevation commonly known as the Levan Ridge (fig. 9). The north basin belongs to the Great Salt Lake drainage area and the south basin to the Sevier River drainage area. The surface water in each has an avenue of escape from the valley, not by way of the low divide at either end, but through a gorge cut into the rock of the west wall. The swampy and alkali conditions show, however, that in recent time the drainage out of the valley has not been vigorous.

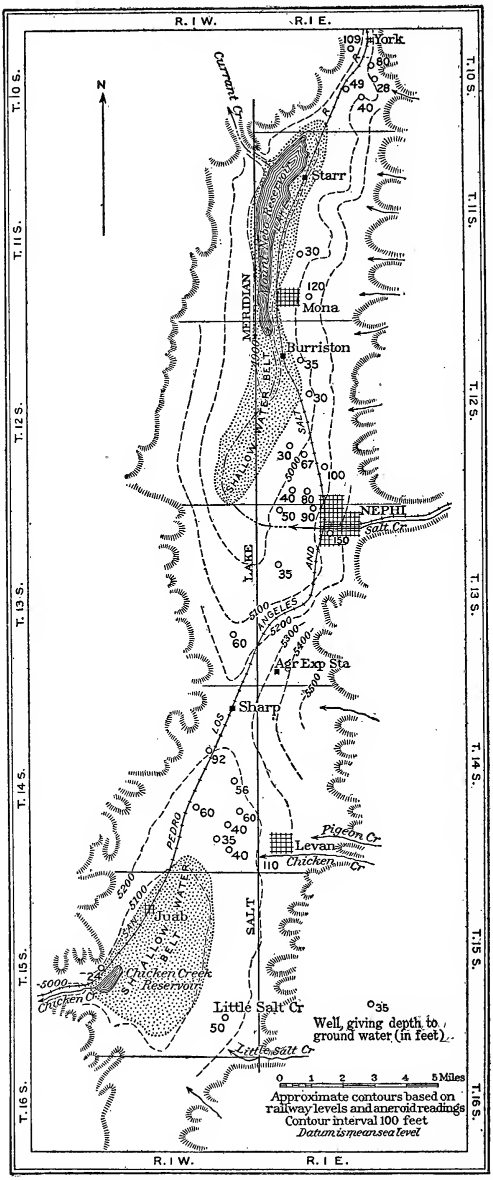


FIGURE 9.—Map of Juab Valley, Utah, showing ground-water conditions.

## RAINFALL.

According to the records of the United States Weather Bureau, the precipitation is greater in Juab Valley than in any other section discussed in this report. (See p. 19 and fig. 3.) At Levan, where observations have longest been made, the average annual rainfall for the last 16 years was 16.58 inches, approximately 40 per cent of which fell in the spring, 13½ per cent in the summer, 20 per cent in the fall, and 26½ per cent in the winter. (See fig. 4.) In recent years considerable success has been attained with dry farming. The principal product is winter wheat, and the usual method is to en-

deavor to raise a crop only in alternate years.[1] The abundant spring rains favor this method of agriculture, but the dry season which usually begins in June is adverse, especially for the late crops.

*Precipitation (in inches) in Juab Valley.*

**Levan.**

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1892 | 1.29 | 0.55 | 2.90 | 1.68 | 1.85 | 0.47 | 0.20 | 0.02 | Tr. | ...... | 0.60 | 2.38 | ...... |
| 1893 | 1.28 | .98 | 3.42 | 2.69 | 1.12 | .00 | .40 | 1.68 | 1.17 | .20 | .96 | 1.85 | 15.75 |
| 1894 | 1.70 | 1.55 | 1.20 | 2.30 | .96 | 1.71 | .95 | .89 | 2.87 | .85 | .00 | 2.75 | 17.73 |
| 1895 | 1.60 | 2.20 | 3.50 | 5.10 | 7.18 | .28 | .84 | 1.04 | .91 | .89 | 1.63 | .95 | 26.12 |
| 1896 | 1.16 | .60 | 1.49 | 1.23 | 1.58 | .36 | 2.26 | .71 | .54 | .50 | 1.58 | .36 | 12.37 |
| 1897 | 1.95 | 1.88 | 2.22 | 1.05 | .85 | .41 | .28 | .14 | 1.84 | 3.29 | 1.23 | 1.65 | 16.79 |
| 1898 | .80 | .25 | 1.45 | 1.06 | 5.57 | .90 | 1.62 | .73 | .00 | .99 | .94 | 1.36 | 15.67 |
| 1899 | 1.43 | 2.25 | 3.96 | .71 | 1.75 | .95 | .25 | 1.06 | .00 | 2.07 | 1.09 | 1.91 | 17.43 |
| 1900 | .87 | .70 | .12 | 3.70 | .57 | .04 | .03 | .28 | 1.70 | .69 | 1.45 | .19 | 10.34 |
| 1901 | .93 | 2.23 | 1.88 | 1.02 | 1.74 | .29 | .25 | 1.55 | .18 | 1.31 | .53 | 1.40 | 13.31 |
| 1902 | .53 | 1.41 | 2.41 | 1.20 | .16 | .03 | .32 | .20 | .91 | 1.62 | 1.98 | 1.72 | 12.49 |
| 1903 | 1.64 | .98 | 1.33 | 2.03 | 2.26 | .48 | .47 | .15 | .92 | 1.56 | .24 | .52 | 12.58 |
| 1904 | 1.71 | 1.93 | 3.25 | 1.00 | 3.13 | .44 | .79 | 1.24 | .27 | .98 | .00 | 1.52 | 16.26 |
| 1905 | .91 | 2.53 | 2.10 | 1.03 | 2.60 | .30 | .34 | .47 | 3.68 | .12 | 1.22 | .94 | 16.24 |
| 1906 | 1.64 | 1.37 | 5.69 | 3.77 | 3.30 | .57 | .79 | 1.31 | 1.74 | .38 | 1.57 | 1.71 | 23.84 |
| 1907 | 3.04 | 2.70 | 1.21 | 1.19 | 2.33 | 1.35 | .43 | 3.57 | .91 | 1.11 | .36 | 1.89 | 20.09 |
| 1908 | .82 | 1.19 | 1.00 | .31 | 4.35 | 1.15 | 1.06 | 1.55 | 2.89 | 1.87 | .63 | 1.40 | 18.22 |
| Average | 1.37 | 1.49 | 2.30 | 1.83 | 2.43 | .57 | .66 | .98 | 1.21 | 1.15 | .94 | 1.44 | 16.58 |

**Nephi.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1904 | ...... | ...... | ...... | ...... | ...... | 0.43 | 0.94 | 0.07 | 0.18 | 1.07 | 0.00 | 1.10 | ...... |
| 1905 | .79 | 1.85 | 2.60 | 1.72 | 1.71 | .26 | .37 | .49 | 2.86 | .05 | 1.23 | .69 | 14.62 |
| 1906 | 1.62 | 1.07 | 4.29 | 3.76 | 3.35 | .61 | 1.45 | 2.31 | .71 | Tr. | 1.81 | 1.36 | 22.34 |
| 1907 | 1.82 | 2.27 | 2.26 | 1.28 | 2.13 | 1.30 | .98 | 1.98 | .64 | .67 | .66 | 2.01 | 18.00 |
| 1908 | .79 | 1.21 | 1.28 | .44 | 4.46 | 1.23 | .61 | 1.31 | 2.62 | 1.63 | .66 | .60 | 16.84 |

## STREAMS.

Juab Valley receives the drainage of about 500 square miles, somewhat more than one-half of which belongs to the north basin. Most of this area is mountainous country which lies east of the valley and gives rise to the creeks that furnish the irrigation supplies. The low ridge to the west has no springs of consequence and gives rise to no permanent streams.

Salt Creek, the largest stream, heads far back in the mountains, receives the drainage from the east side of Mount Nebo, flows through a canyon between the Wasatch Mountains and San Pitch Mountains, and enters the valley at Nephi, which it supplies with water for irrigation. North of Salt Creek a number of small streams issue from the high mountains and furnish irrigation supplies for ranches and small settlements that extend from Nephi to the north end of the valley. The surplus water that reaches the lowest part of the basin is there stored, and is eventually led, through the canyon that forms the north outlet of Juab Valley, into Goshen Valley, where it is utilized for irrigation. (See fig. 9.)

[1] Farrell, F. D., Dry-land grains in the Great Basin: U. S. Dept. Agr., Bur. Plant Industry, Circular 61, 1910.

The largest streams tributary to the south basin are Chicken Creek and Pigeon Creek, which provide the irrigation supplies for the settlement of Levan. Farther north Fourmile Creek, a small stream, flows out upon the Levan Ridge, where it supplies a ranch and a dry farm. About 8 miles south of Levan, Little Salt Creek enters the valley and furnishes irrigation water for a few families, and near the south divide a small stream debouches from Chriss Canyon. The surplus water in the south basin is utilized in much the same manner as that in the north basin. It is stored in a reservior in the low central flat, whence it is led, through the south outlet of Juab Valley, upon lower ground in Little Valley. (See fig. 9.)

### SPRINGS.

In the north basin a chain of seepage springs extends along the foot of the east slope, which receives the principal supply of water from the mountains. In the south basin an important group of springs occurs on the farm of Arthur Meads (NW. $\frac{1}{4}$ sec. 2, T. 15 S., R. 1 W.), at the foot of the alluvial fan of Chicken Creek. It is probably fed largely by the irrigation waters applied to the Levan fields.

The springs in both basins are employed to some extent for irrigation, but much of the water goes to waste or is used to poor advantage on low-lying grass lands. Water from Meads's Spring is led by gravity through a pipe line to the railway tank at Juab station and is there used for locomotive supplies.

The discharge of some of the springs varies notably with the different seasons, the yield being greatest from July to October, and least in the latter part of winter. This fluctuation shows that the ground water responds to the seasonal variations in precipitation, but with a lag of several months, for the heaviest rainfall and the largest supplies from the melting of the snow in the mountains occur in the spring while the least precipitation is in the summer.

### FLOWING WELLS.

In the low central part of the north basin (Pl. I) numerous flowing wells are found for a distance of about 12 miles, from a point north of Starr nearly to a point in the valley due west of Nephi. The position of most of these wells on the east side of the central axis is due chiefly to the fact that the principal ground-water supply comes from the east, but is probably in part also due to the fact that the ranches and settlements are on the east side and therefore most of the drilling has been done there. The flowing wells range in depth from about 80 feet to somewhat more than 300 feet, and without doubt all are supplied from beds of sand and gravel in the valley fill. Nearly all are 2 inches or less in diameter, and their natural flow

ranges from a fraction of a gallon a minute to a maximum of about 30 gallons a minute. Their yield is said to vary in a manner somewhat like that of the springs, the largest discharge being in summer and fall, and the smallest in the latter part of winter. Several wells near the margin of the area of flow are so sensitive to climatic conditions that they may cease to flow during or immediately after dry seasons. The locomotive supply at Starr is furnished by a 1½-inch flowing well from which the water rises into the tank by artesian pressure.

The low central tract of the south basin is somewhat wider but not nearly as long as that of the north basin, and its ground-water resources have been less thoroughly explored. Until recently the only flowing well in this basin was that of N. M. Taylor, at Juab. This well is 2 inches in diameter and 130 feet deep and discharges several gallons per minute. It is situated on relatively low ground, but it is west of the center of the valley and rather remote from the east slope which is the main source of water supply. The water rises to at least the level of the railway, which is here 5,077 feet above the sea, or about 150 feet above the level reached by the artesian water in the north basin.

In the summer of 1908 a prospect hole for oil was put down about one-half mile east of Juab. It was 12 inches in diameter at the top and 6 inches at the bottom and reached a depth of 560 feet. Water was struck at different levels and when the drill reached a depth of 165 feet the water rose above the surface and overflowed at a rate estimated by the driller at about 200 gallons per minute. The drilling was finally stopped because of the abundance of water. The entire hole is said to penetrate valley deposits. The section to the depth of 353 feet is reported by the driller as follows:

*Section of well east of Juab.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Sand and gravel | 30 | 30 |
| Coarse gravel (water) | 10 | 40 |
| Blue clay | 5 | 45 |
| Quicksand and gravel (water) | 75 | 120 |
| Conglomerate | 7 | 127 |
| Yellow clay | 3 | 130 |
| Gravel, with layers of quicksand and clay (flow) | 35 | 165 |
| Conglomerate alternating with blue and yellow clay | 188 | 353 |

In the center of the valley in both basins the sediments washed in from the mountains no doubt extend to considerable depths, and the lower portions probably include beds of gravel that contain water under fully as great pressure as the shallower beds that have hitherto provided the flows. Artesian water should not be expected on the

bench lands, but the amount of water recovered through flows in the low areas could be increased if wells of larger diameter and somewhat greater depth were drilled.

### GROUND WATER BENEATH THE BENCHES.

In the two low central areas in which flows are obtained ground water is invariably found near the surface and springs are abundant. In passing from these central areas up the slopes toward the mountains, the ground water occurs at greater depths as the altitude increases. Where flows are not expected, the wells are usually dug by hand and are not sunk far below the level at which the first water is found. Though the yield of such wells is not large, it is generally sufficient for domestic and stock uses.

In the vicinity of York, at the north end of the valley, about a dozen wells have been sunk. Some of these wells found seeps at a depth of less than 30 feet; others were carried to depths of over 100 feet. (See fig. 9.) In the village of Mona the domestic supplies are derived chiefly from wells ranging in depth from a few feet to more than 100 feet, according to the altitude of the surface. At Nephi, which is located on the alluvial fan of Salt Creek, far above the low central area in which flows are obtained, there are at present no wells, but a successful well about 160 feet deep was at one time sunk. Farther down the slope, northwest, west, and southwest of the city, a number of wells have been dug, their depth depending on the altitude of the surface. On the west side of the north basin wells are scarce, but ground water in sufficient quantities for domestic and stock purposes can probably be obtained, especially under the lower parts of the slope.

A number of wells have been dug in the fields below Levan, and ground water could probably be found beneath the village at depths not greatly exceeding 100 feet. A few wells have also been sunk south of Levan and in the region northwest of Levan, to within 1¼ miles of Sharp station. At the Little Salt Creek settlement there are several wells about 50 to 100 feet deep. On the farm of the Juab Development Co., in sec. 19, T. 15 S., R. 1 W., just west of Chicken Creek reservoir and near the west margin of the valley, a well was drilled into rock and carried to a depth of 620 feet before obtaining a satisfactory yield. The water in this well rises to a level 22 feet below the surface.

Nearly all the wells in this valley are found within the areas in which the ground water is less than 100 feet below the surface (fig. 9), but recent dry-farming developments have created a demand for water supplies farther up the slopes, especially on the Levan Ridge. The ordinary failures of attempts to find water in the higher

areas are readily explained by the fact that sufficient account was not taken of the altitude, the holes having been abandoned before there was any reason for expecting water. It is probable that wells sunk some distance beyond the limits of existing wells will be successful if digging or drilling is carried to sufficient depths, but the upper parts of the slopes should of course be avoided.

The most southerly well in the north basin is located about 2½ miles north of Sharp Station and has water at a depth of about 60 feet. The most northerly well in the south basin is that of Grace Bros., in the NW. ¼ sec. 14, T. 14 S., R. 1 W., just west of the railway and about 1¼ miles southwest of Sharp (fig. 9). This well is 102 feet deep and its section is said to consist almost entirely of red clay, in which a seep was obtained at the depth of 92 feet. About 2 miles south of Sharp and at a somewhat lower level than the Grace Bros.' well, is the well of J. W. Paxman, which is 56 feet deep and yields generously. In the last two wells the water stands at a level of about 5,100 feet above the sea, or not much more than 100 feet below the surface at Sharp, which has an elevation of 5,224 feet. This station is situated at approximately the lowest point of the divide between the north and south basins, and eastward from it the surface rises at the rate of about 100 feet per mile for several miles, beyond which the grade becomes steeper. (See fig. 9.) These relations give a basis for forecasting the depth to the ground-water table beneath the Levan Ridge.

## QUALITY OF WATER.

The ground water in Juab Valley is hard, but, as a rule, is otherwise of good quality, this being true even of wells and springs in close proximity to alkali soils. A few of the shallow wells, especially on the west side, are reported to yield somewhat saline water, but here water of better quality can probably be found by tapping a deeper bed. The quality of the water used at Starr as locomotive supply is shown by the following analysis. This water is derived from a flowing well about 100 feet deep.

*Analysis of water from the railway well at Starr.*

| | Parts per million. |
|---|---|
| Total solids | 267.5 |
| Siliceous matter ($SiO_2$) | 4.5 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 1 |
| Calcium carbonate ($CaCO_3$) | 112 |
| Magnesium carbonate ($MgCO_3$) | 52 |
| Sodium chloride ($NaCl$) | 23 |
| Magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), volatile, organic and loss | 75 |

### IRRIGATION WITH GROUND WATER.

Much of the water that sinks into the gravelly deposits in the upper parts of the slopes, reappears in the low wet areas along the central axis of the valley, where it goes to waste or is put to poor use. A large part of this surplus ground water could be recovered through wells before it reaches the central areas and could be applied to fertile soil that is now idle for lack of water.

Up to the present time irrigation with ground water has not been attempted except on a very small scale, chiefly from 2-inch flowing wells. Though more water could be obtained from flowing wells than is at present derived from this source, yet the possibilities of irrigating with artesian water are limited by the fact that much of the low land where copious flows can be obtained is too poorly drained and contains too much alkali to be successfully cultivated. If wells were drilled on somewhat higher ground and pumps were installed, water could be recovered in larger quantities and applied to better land. Before pumping plants are installed the precautions discussed on pages 49–53 should be taken. Pumping plants could probably be best employed in providing supplementary supplies for the latter part of the growing season, when the flow of the streams diminishes.

### CULINARY SUPPLIES.

At Nephi water for domestic uses is derived from springs and led to the city through a gravity pipe line. At Levan the stream water that flows through the village is used. At Mona and most of the smaller settlements and isolated ranches the drinking and culinary supplies are obtained from wells. For some of the dry farms water is hauled from distant sources.

## ROUND, LITTLE, SAGE, DOG, AND FERNOW VALLEYS.

### TOPOGRAPHY.

The mountainous region west of Juab and Sevier valleys embraces a north-south trough in which lie several small valleys that contain tracts of arable land. West of this trough are the East Tintic, Canyon, and Pavant ranges, which form the highest part of the mountainous region; east of the trough is a group of lower ridges, the southern part of which is known as the Valley Range. Sevier River breaks into this trough through a gap in the east rim, flows northward for about 10 miles in what is locally known as Little Valley, and then escapes into Sevier Desert through a deep canyon cut into

the lofty west wall. Before the river leaves Little Valley it is joined by the channel of Chicken Creek, which enters from the south basin of Juab Valley through another gap in the east rim. Farther north a rock-ribbed region, including Sage, Dog, and Fernow valleys, and a small part of East Tintic Valley, is drained, at least potentially, into this section of Sevier River. At the south end of the trough lie Upper and Lower Round valleys. (See Pl. I.)

### GEOLOGY.

The oldest rocks in this region consist of indurated Paleozoic quartzites and limestones which have been folded and greatly eroded. They lie at the surface in many localities, chiefly in the northern part of the region, and form the core of the Canyon and Pavant ranges. Younger strata, consisting mainly of red and buff conglomerates, sandstones, and shales, rest upon the irregular erosion surface of the quartzites and limestones, producing a pronounced unconformity, which is well displayed on the east flank of the Canyon Range. These younger strata are believed to be, at least in part, of early Tertiary age. They do not occur at the north end of the region, but they form the east wall of Sage Valley and become increasingly prominent south of Sevier River until, in the Round Valley area, they conceal the older formations almost entirely. They are less folded than the Paleozoic strata but are fractured and faulted and in this region they generally dip toward the east. In Fernow and Dog valleys the Paleozoic formations are partly covered by volcanic rocks, which are probably younger than the Tertiary sediments.[1]

### RAINFALL.

The following table presents a record of the monthly precipitation at Scipio, in Round Valley, where observations have been made for the United States Weather Bureau since 1894. The average annual precipitation at this point is somewhat less than at Levan, about the same as at Fillmore, and decidedly more than in the desert region farther west. (See p. 19 and fig. 3.) Approximately 35 per cent of the precipitation occurs in the spring, 14 per cent in the summer, 24 per cent in the fall, and 27 per cent in the winter. (See fig. 4.) Dry farming has been undertaken on a large scale in Dog and Little valleys, the principal crop being winter wheat.

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[1] Smith, G. O., Tintic special folio (No. 65, Geol. Atlas U. S., U. S. Geol. Survey, 1900, p. 2.

*Precipitation (in inches) at Scipio.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1894 | ...... | ...... | ...... | ...... | ...... | ...... | .68 | 1.53 | 2.08 | ...... | .00 | 2.00 | ...... |
| 1895 | .58 | ...... | 2.12 | ...... | ...... | .33 | .42 | .28 | .38 | .83 | 1.35 | .80 | ...... |
| 1896 | 1.22 | .10 | 1.51 | 1.06 | 1.36 | Tr. | 2.82 | 1.59 | .89 | 1.53 | 1.14 | .40 | 13.62 |
| 1897 | 2.60 | 2.61 | 3.26 | 1.26 | .73 | .21 | .42 | .38 | 1.39 | 3.34 | 1.55 | 1.49 | 19.24 |
| 1898 | 1.89 | 1.62 | 3.41 | .35 | 2.83 | 1.10 | .19 | .44 | .00 | ...... | 1.36 | 1.10 | ...... |
| 1899 | 1.40 | 2.28 | 3.85 | .51 | .70 | .43 | .58 | 1.03 | .00 | 2.06 | .83 | 1.85 | 15.52 |
| 1900 | 1.04 | .20 | .10 | 2.09 | .01 | .10 | Tr. | .37 | 1.17 | .57 | 1.17 | .10 | 6.92 |
| 1901 | .60 | 2.43 | 1.02 | 1.07 | .83 | .27 | 1.12 | 2.67 | .10 | 1.31 | .51 | .76 | 12.69 |
| 1902 | .80 | 1.61 | 2.25 | 1.17 | .84 | .08 | .07 | .21 | 1.38 | .56 | 2.31 | .47 | 11.75 |
| 1903 | 1.51 | .86 | 1.59 | 1.83 | 1.96 | .36 | .27 | .17 | .98 | .67 | .48 | .33 | 11.01 |
| 1904 | .82 | 1.74 | 3.21 | .27 | 2.01 | .28 | .50 | .51 | .30 | .95 | .00 | 1.99 | 12.58 |
| 1905 | .67 | 4.70 | 2.58 | 2.00 | 3.08 | .09 | .43 | 1.01 | 2.88 | .53 | 2.66 | .50 | 21.13 |
| 1906 | 1.73 | 1.08 | 3.97 | 3.07 | 2.12 | .71 | .46 | 1.64 | 1.68 | .17 | 1.99 | 1.44 | 19.99 |
| 1907 | 2.39 | 2.35 | 1.41 | 1.19 | 1.80 | 1.22 | .67 | 2.17 | .73 | 1.35 | .28 | 2.67 | 18.03 |
| 1908 | .16 | 1.09 | .94 | .46 | 3.56 | .68 | .98 | 1.48 | 2.09 | 3.33 | .46 | .74 | 15.97 |
| Average | 1.24 | 1.74 | 2.23 | 1.26 | 1.68 | .42 | .64 | 1.03 | 1.21 | 1.32 | 1.07 | 1.10 | 14.87 |

## WATER SUPPLIES.

### ROUND VALLEY.

At the south end of the mountainous trough lies Upper Round Valley, which is hemmed in on the east and south by the Valley Range and on the west by the precipitous up-faulted wall of the Pavant Range, but which opens northward into Lower Round Valley. The lower valley, in which is located the village of Scipio, is bounded on the east by the Valley Range, on the west by the Pavant and Canyon ranges, and on the north by a low ridge, through which has been cut a gap that is no longer functional as an outlet for the drainage.

The water supply comes from a series of large springs and spring-fed streams near the head of the upper valley, the principal sources being Maple Grove Spring, Rock Creek, Phoero Creek, and Willow Creek. (See Pl. I.) The water flows to a depression near the outlet of the upper valley, where a reservoir has been constructed, and is thence allowed to flow to the lower valley, where it is used by the people of Scipio for irrigation. Any surplus water collects in the lowest part of the valley. Faintly outlined strands show that at some time in the past the lower valley held a lakelet with an area of several square miles. North of the pass to Holden there are several canyons that contain springs and small intermittent streams, but their discharge is not large enough nor regular enough to be of much value for irrigation.

The upper and the lower valley each constitutes a relatively independent rock basin containing a rather thick deposit of loose sediments that are partly saturated with water. In the lower valley there are many wells, most of which are in or near Scipio, where they furnish the greater part of the supply for drinking, household. and

stock use. The ground-water level fluctuates with the rainfall and the amount of irrigation water that is used. In the southeastern part of Scipio the depth to water is more than 100 feet, but on the lower ground in the northwestern part of the village and in the adjacent area to the west it is generally less than 10 feet. Two test wells have been sunk in the hope of obtaining flows. One was drilled in the village square and is said to have been carried to a depth of over 300 feet, apparently all in loose valley deposits. The other was drilled near the residence of H. Esklund, one-half mile or more west of the square and at a lower altitude. In both wells the water from the deeper beds rose fully to the level of the superficial ground-water table, but in neither was a flow obtained. In the shallow-water belt ground water could probably be profitably pumped for irrigation. In the southeastern part of the village, where water from the irrigation ditches is used for household purposes, more satisfactory supplies could be obtained by sinking wells.

### LITTLE VALLEY.

Little Valley may be said to constitute the valley of Sevier River from the Sevier Bridge dam to the point where it enters the canyon in the Canyon Range. (See Pl. I.)

In the level reach above the canyon the river has only a slight grade and is bordered by swampy bottom lands on which a dozen or more flowing wells have been drilled. (See Pl. I.) They are located on sections 15, 21, 22, 23, 27, 28, and 34, in T. 15 S., R. 2 W. Most of them are 2 inches in diameter and pass through clay, sand, and gravel to depths of a little over 50 feet. The water rises only a few feet above the level of the river and the yield is generally less than 10 gallons a minute. The land on which the flows are obtained lies so low that it is not possible to make much use of the water for irrigation. Several springs of good size also occur near the river.

On the east side of the valley, a short distance south of Chicken Creek, a well 2 inches in diameter and 320 feet deep was drilled for the Juab Development Co. It is said to end in valley sediments without reaching rock, and the water rises within 18 feet of the surface or slightly above the river level. This well is frequently pumped continuously for several hours at the rate of 5 gallons per minute.

The west side of the valley is occupied by a broad upland belt which is underlain in part by Tertiary strata that are dissected into a sort of bad-land topography and in part by younger sediments. In the lower portions of this belt, lying near the river, there will probably be no difficulty in obtaining enough water for domestic and stock use by sinking to moderate depths in the valley sediments, but on the higher levels the prospects are not good.

### SAGE VALLEY.

Sage Valley lies north of Little Valley and its surface rises gradually from Sevier River to the rocky ridges that separate it from Dog Valley. (See Pl. I.) As far as was ascertained, it contains no spring, stream, or well. Wells sunk near the south end, where the surface is low and the valley sediments are generally deep, would doubtless obtain water, but farther north these sediments are likely to be drained and drilling would be an uncertain undertaking.

### DOG AND FERNOW VALLEYS.

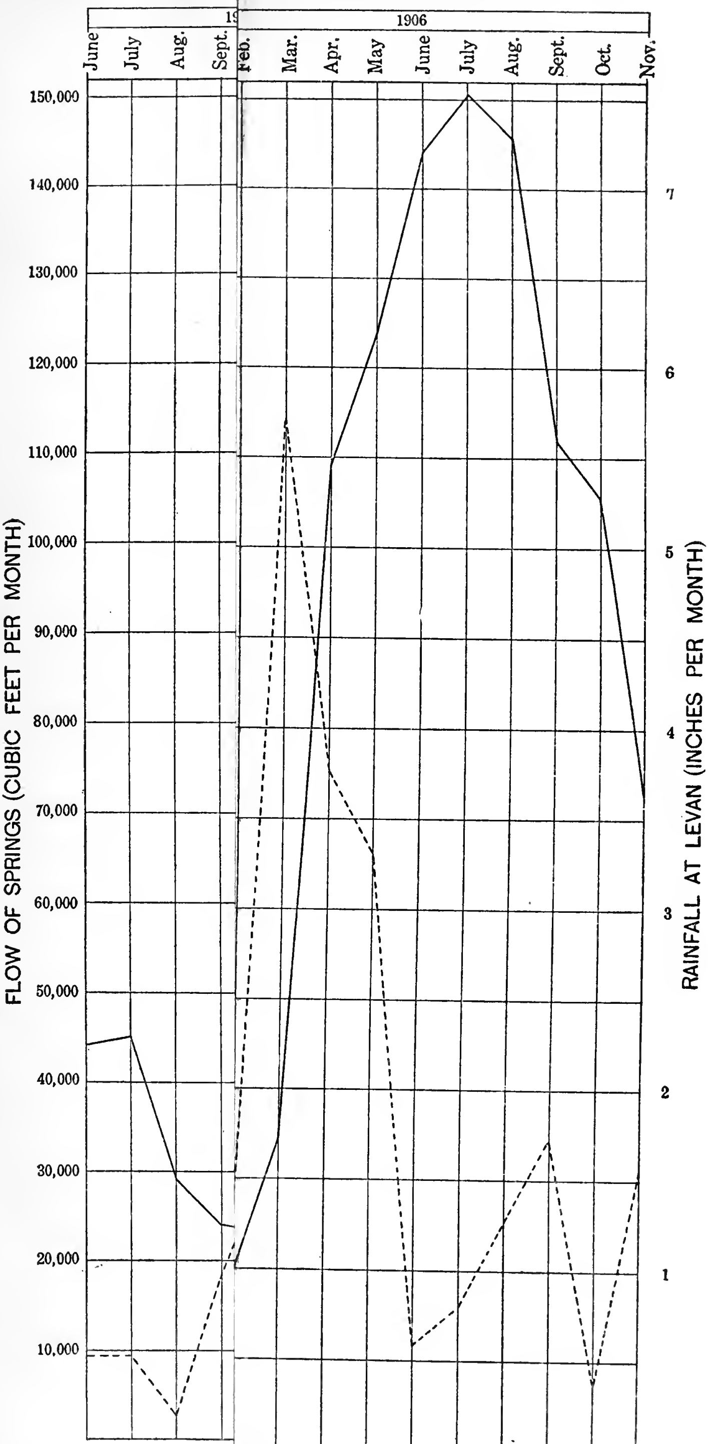
Dog and Fernow valleys lie several hundred feet above Juab Valley and Sevier River, and are hemmed in on all sides by rocky walls consisting of Paleozoic limestones and quartzites and Tertiary igneous rocks. The rock of both valley floors are in most places covered with loose sediments, but irregularities of the surface as well as exposures of the bed rock in certain localities indicate that the average thickness of these sediments is not great. Both valleys have gorge-like outlets toward the south, but neither has any permanent stream. At the north end of Fernow Valley several small permanent springs issue from the porous mantle of disintegrated material that covers the impervious igneous rocks at the head of the valley. Recently a pipe line about 5 miles long has been laid from one of these springs to the headquarters of the Utah Arid farm, in Dog Valley.

There is no well in either valley, but two unsuccessful attempts to obtain ground water have been made in Dog Valley—the first, a dug hole about 75 feet deep, in which no water was found; the second, a drilled hole put down in 1908 by the State of Utah. At a depth of 230 feet in the drilled hole no water had been found, but some sort of hard rock was encountered and the project was abandoned. There are no surface indications that the unconsolidated sediments contain water. The underlying limestones are likely to be traversed by fissures or solution passages which may allow the storm water that seeps into the unconsolidated sediments to escape to lower levels.

## TINTIC VALLEY.

### GENERAL FEATURES.

Tintic Valley extends for nearly 30 miles in a north-south direction and comprises more than 300 square miles (Pl. I). It is walled in on the east and northeast by the East Tintic Mountains, on the southeast by the Canyon Range, and on the west by the West Tintic and Champlin mountains, its outlet being toward the south through a constricted portion of the valley.




O PRECIPITATION.

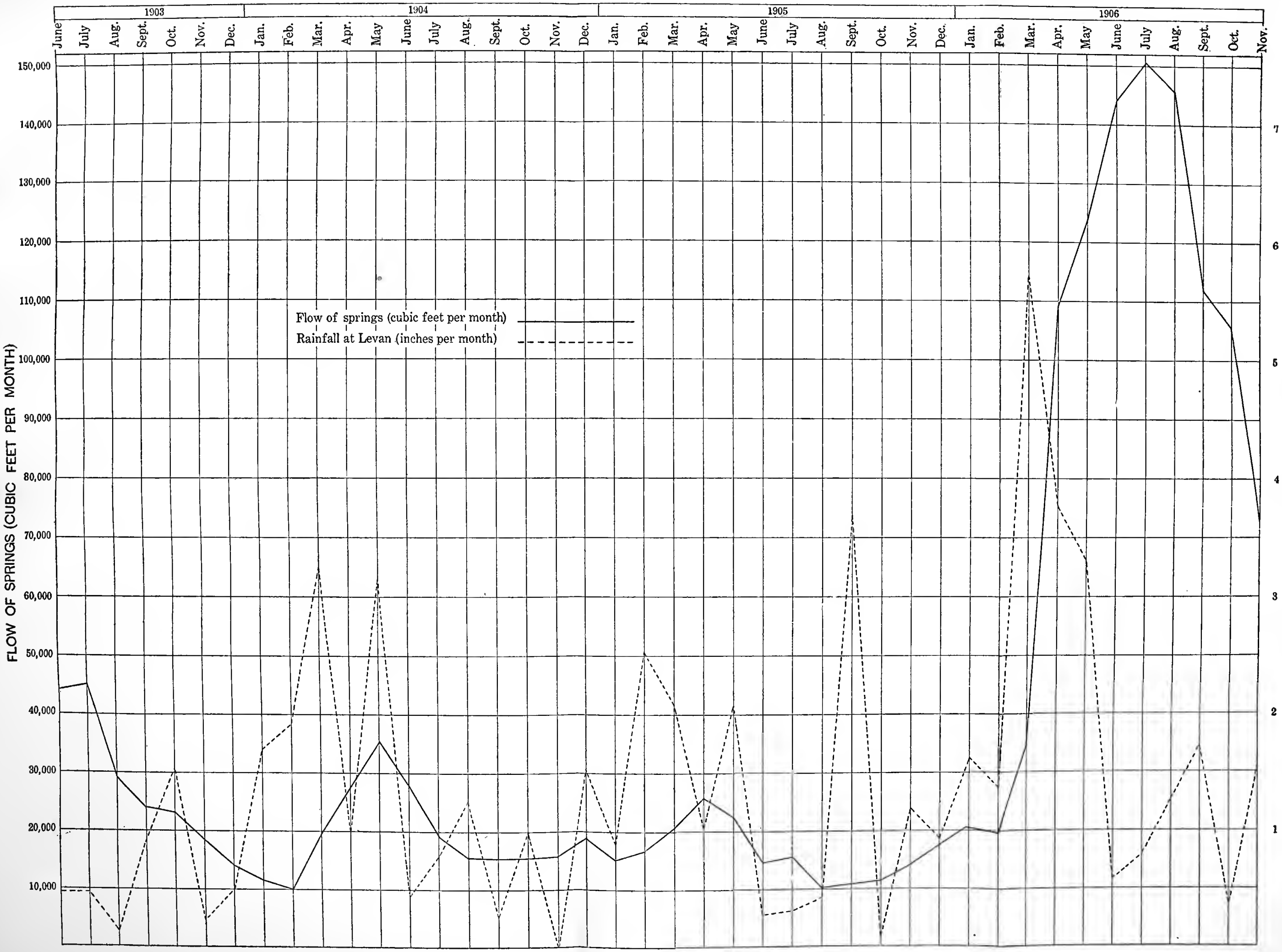



DIAGRAM SHOWING FLOW OF THE SPRINGS THAT SUPPLY SILVER CITY AND THE RELATION OF FLOW TO PRECIPITATION.

The stream channel which marks the central axis descends from about 6,000 feet above sea level, near the north end, to 4,900 feet where it enters the Sevier delta region, 200 feet above Sevier River. The alluvial slopes that extend from the mountain borders to the center of the valley are steep and gravelly, and are dissected to an unusual degree, the erosion topography in many places giving a relief of over 100 feet. The central draw is depressed below the adjoining bench lands out of which it has been excavated, and south of Jericho it expands to form the flat bed of ancient Lake Bonneville, bordered by terraces of the Bonneville stage. The draws or stream valleys that are cut into the unconsolidated sediments are probably chiefly relics of the humid epoch when Lake Bonneville existed.

Cedars and large sagebrush are found on the upper parts of the slopes, and rabbit brush grows in the draws, that collect some moisture. On the old lake bed the vegetation is dwarfed and scanty. No rainfall observations are available for this region, but the character of the vegetation seems to indicate less intense aridity than in the region farther west. The high bench land is gravelly and the low draws and lake bed show indications of alkali, but areas of what appears to be good soil are found at intermediate levels.

The San Pedro, Los Angeles & Salt Lake Railroad enters the region through Boulter Pass at the north end, extends southward through the entire length of the valley, and makes its exit through the outlet at the south end. Except for the people at the McIntyre ranch, in the heart of the valley, and a few railroad employees the valley is virtually destitute of permanent inhabitants. Dry farming has not been seriously attempted.

## WATER RESOURCES.

In the mountains at the head and sides of the valley springs are numerous, but they are widely scattered and are not of sufficient size to be of much value for irrigation nor to give rise to streams of any importance. Consequently the broad alluvial slopes are destitute of water except on rare occasions when the snow melts or a rainstorm occurs and a mud-laden flood courses down the arroyos. The only partial exception to this condition is the valley of Cataract, or Death, Creek, which heads in the highest part of the West Tintic Mountains and leads southeastward toward McIntyre and which in some seasons contains a small stream.

Although little prospecting has been done, there is evidence that water exists in the valley deposits and that the central draw along a part of its course has been eroded to the ground-water level.

In the vicinity of the McIntyre ranch, which is near the station of McIntyre, sec. 28 (?), T. 11 S., R. 3 W., near the junction of the

main Tintic draw with the draw of Death Creek, the flat-bottomed and deeply intrenched stream valleys receive numerous seeps and small springs that make it possible to raise a little grass and grain. At the old smelter, a short distance north of the ranch house, ground water was at one time tapped by running tunnels to distances of several hundred feet beneath the benches adjoining the valley, and water still flows from these abandoned tunnels. At this point there is also a shallow open well and a 2-inch flowing well, which is about 90 feet deep and usually yields several gallons per minute, though it is known to have stopped flowing in summer. At the ranch house there is a flowing well, said to be 190 feet deep, which yields a small supply of water. (See Pl. I.)

About midway between McIntyre and Jericho stations, in ravines on the east side of the railway, are several small springs, variously known as Cazier Spring, Squaw Bush Spring, Twin Springs, etc. (Pl. I), which, together with the Riley Springs in the mountains, furnish the railway supply at Jericho, the water being led to this station through pipe lines by gravity.

In the valley, a few miles south or southwest of Jericho, several wells have, at different times, been dug to depths of 50 to 100 feet, and fairly good supplies of water have been found.

About 2 miles north of McIntyre station, in a draw on the east side of the railway, there was at one time a well about 60 feet deep, which is said to have had good water and to have been pumped by a windmill.

About 1½ miles northwest of Tintic Junction, a short distance west of the railway, and situated on dissected bench land, is a dug well belonging to G. A. Franke, which is 165 feet deep and contains about 12 feet of somewhat mineralized water. In a ravine southwest of the Franke well, and a short distance north of the Cherry Creek pipe line, is another dug well, which is said to have found good water at a depth of about 50 feet.

The steep, gravelly character of the alluvial slopes makes it probable that beds of sand and gravel extend to the center of the valley, and the springs and wells that have been described give reason to believe that these porous beds are saturated below a certain level and that wells sunk to moderate depths in the lower parts of the valley will be successful; but as the ground water is not under sufficient head to rise to the level of the more fertile land, little irrigation will probably be possible from flowing wells. On the higher ground in the peripheral parts of the valley the depth to water is in all probability too great to make its recovery practicable.

In most places the limestone and quartzite formations of this region dip away from the valley, and other conditions are unfavorable for obtaining water by drilling into rock.

### QUALITY OF THE WATER.

The water from most of the wells and springs in this valley is of fairly good quality and is considered satisfactory for drinking and for culinary uses. The result of an analysis, made in September, 1903, of the water from Cazier Spring, which is used by the railroad company for locomotive supplies, is presented in the following table:

*Analysis of water from Cazier Spring, in Tintic Valley.*

[Parts per million.[1] Analyst, Herman Harms.]

| | |
|---|---|
| Total solids | 508 |
| Siliceous matter ($SiO_2$) | 57 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 3.5 |
| Calcium carbonate ($CaCO_3$) | 137 |
| Calcium sulphate ($CaSO_4$) | 38 |
| Magnesium carbonate ($MgCO_3$) | 39 |
| Sodium chloride ($NaCl$) | 163 |
| Calcium chloride ($CaCl$) | Trace. |
| Magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), volatile, organic, and loss | 70 |

## TINTIC MINING DISTRICT.

### GEOLOGY.

The Tintic mining district, one of the oldest and most productive in the State, is located near the north end of the East Tintic Mountains. The geology of the region has been described in detail by George Otis Smith.[2]

The indurated rocks belong to two distinct groups: A thick stratified series, consisting chiefly of Paleozoic limestones and quartzites, and a series of igneous rocks of Tertiary age. After the stratified rocks had been compressed into large folds and had been somewhat fractured and faulted they were extensively eroded. Later they were invaded and in large part covered by the Tertiary lavas, which, in their turn, have also been submitted to prolonged weathering and erosion. The two systems differ radically in their relations to ground water.

### WATER IN LIMESTONE AND QUARTZITE.

The areas underlain by the Paleozoic stratified rocks are practically destitute of springs and wells (fig. 10) and the rocks themselves are barren of water to great depths, several of the mines in this region having been sunk to low levels without finding water or passing beneath the zone of oxidation. According to reports, the Eureka

[1] Originally reported in grains per gallon.

[2] Tintic special folio (No. 65), Geol. Atlas U. S., U. S. Geol. Survey, 1900.

Hill mine has reached a depth of 1,500 feet (4,976 feet above sea level), the Centennial mine a depth of 1,800 feet (5,093 feet above sea level), and the Mammoth mine a depth of 2,260 feet (4,780 feet above sea level), each without finding water, while in the Gemini mine water is reported at the 1,600-foot level (4,867 feet above the sea), and a pump is operated at the rate of about 100 gallons per minute. Apparently such fractures as exist in the limestone allow the water to descend to profound depths.

## WATER IN IGNEOUS ROCKS AND OVERLYING WASTE.

### SPRINGS.

As is shown in figure 10, numerous springs are found in those parts of the mountains where igneous rock constitutes the surface formation. The rock itself is nearly impervious, but its upper portion has been disintegrated into loose, porous, gritty materials, with which it is covered in localities that are sheltered from active erosion. The rain percolates into the débris mantle, but is prevented from descending far because of the underlying unweathered rock. Accordingly, the ground water either accumulates or seeps along the surface of the firm rock until it reaches a point where the rock crops out and the water is returned to the surface in the form of a spring or seep.

Most of these springs are small, and as they are fed from shallow sources their flow varies greatly. In figure 10 the yield of a group of springs, whose water is led through a pipe line to Silver City, is plotted for a period of three and one-half years, during which their flow was measured, and on the same diagram is shown the precipitation for this period at Levan, one of the nearest points at which rainfall observations were made. The diagram shows that the yield fluctuates widely and that the fluctuations follow those of the rainfall with but slight lag. This diagram should not be given too strict an interpretation because the rainfall in the vicinity of the springs may have had a somewhat different distribution than at Levan and also because of repairs that were made on the system and meter within this period. Nevertheless, the records for this region show conclusively that the heaviest rainfall occurs in the spring months, and these spring rains no doubt account for the increase in flow shown in this season each year. Moreover, the radical increase in flow in 1906 is clearly the result of an abnormal amount of precipitation at that time, for the records of the 11 stations for which data are given in this report all show more than the average amount of rainfall during this year, and 9 show more rainfall during this year than during any other in which records were kept.

Springs of this type furnish supplies for Silver City, Jericho, and the Utah Arid farm, in Dog Valley.

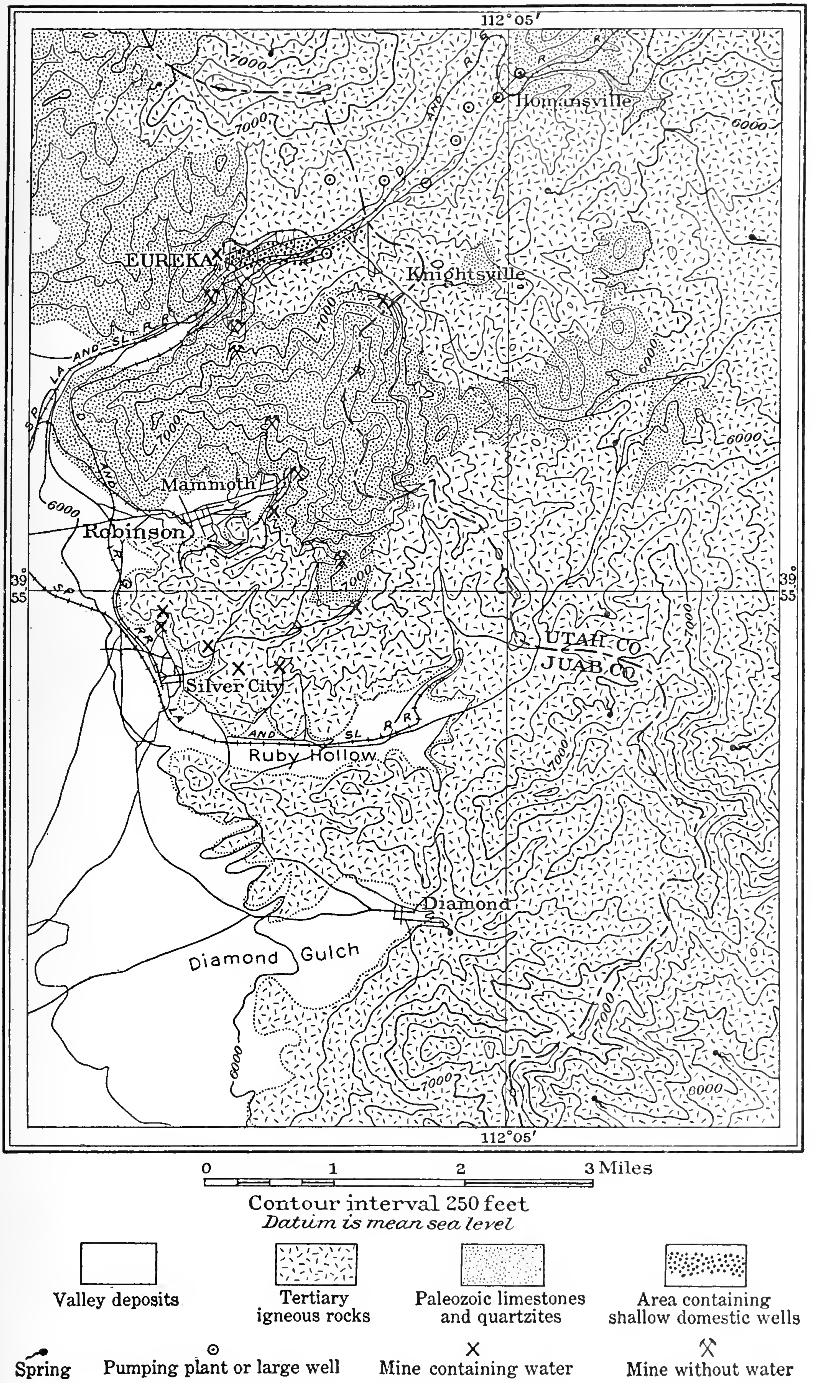



FIGURE 10.—Map of Tintic mining district, showing the relation of the water supply to the igneous rocks. (Geology after George Otis Smith, Tintic special folio.)

## WELLS.

Valuable supplies of water are derived from wells and infiltration galleries in the sediments overlying the igneous rocks and in the partly disintegrated upper portion of the rocks themselves. These wells are situated in the Eureka and Homansville gulches, which are on opposite sides of the main divide. (See fig. 10, p. 83.) The upper part of each of these valleys is underlain by igneous rocks, is relatively broad and open, and is mantled with residual waste and sediments carried down from the mountain sides; but farther down in each valley the igneous rocks give way to the more resistant limestones and quartzites, and the valleys accordingly become more constricted and canyon-like. The wells are found in the upper parts of the valleys, as shown in figure 10.

In Eureka there are many private wells that are dug to depths ranging from about 15 to 125 feet. Most of these wells extend to the hard rock or are sunk a short distance into the rock, and they derive their meager supplies from seepage near the bottom of the loose materials. Near the divide and in the Homansville Basin greater quantities of water are recovered through large vertical shafts and horizontal tunnels that afford extensive infiltration surfaces. Two of these plants may be considered typical.

The water for the Gemini pumping station in the Homansville Basin is obtained from one or more shafts which are 60 feet deep and end in partly decomposed rock, and from two tunnels at the 60-foot level, which are about 5 by 7 feet in cross section and have a combined length of about 900 feet. At the time the plant was visited the water level was only 20 feet below the surface, but it is reported to descend nearly to the bottom in dry seasons. The pump is operated about 14 hours each day at the rate of 27 gallons per minute, and the engineer in charge estimated that the maximum yield for continuous pumping is only about 25 gallons per minute. The water is considered satisfactory for use in boilers.

At the Eureka Hill pumping plant, situated a little farther northeast in the same basin, there is a main shaft, about 4 by 6 feet in cross section, that extends to a depth of 265 feet, largely through incoherent materials consisting of clay, bowlders, and sand; two other shafts; and tunnels at the 65-foot and lower levels, said to aggregate several thousand feet in total length. At the time the plant was visited it was reported that the normal water level was 20 feet below the surface but that the water in the well was drawn down to 60 feet below the surface by pumping. The pump is operated at the rate of about 80 gallons per minute for about 5 to 12 hours each day, fully 50,000 gallons being withdrawn on certain days. The water is only moderately mineralized but varies considerably in mineral con-

tent, probably with changes in the water level. The following table presents two analyses of this water made by the Dearborn Drug & Chemical Co.:

*Analyses of Homansville well water.*[1]

[Parts per million.]

| | August, 1895. | June, 1897. |
|---|---|---|
| Total solids | 400 | 320 |
| Silica ($SiO_2$) | 60 | 48 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 9.9 | 1.2 |
| Calcium (Ca) | 44 | 55 |
| Magnesium (Mg) | 29 | 26 |
| Sodium and potassium (Na+K) | 65 | 33 |
| Bicarbonate radicle ($HCO_3$) | 163 | 146 |
| Sulphate radicle ($SO_4$) | 65 | 35 |
| Chlorine (Cl) | 48 | 49 |

[1] These analyses were originally given in hypothetical combinations and in grains per gallon. All of the carbonates have been recalculated as bicarbonates.

The Homansville wells furnish good illustrations of the fact that, if the filtration surfaces are made sufficiently extensive, important quantities of water can be recovered from materials whose specific yield is very small.

## MINES.

Near Silver City there are many old mines that have been developed entirely in igneous rocks. They have invariably encountered water that descends along the veins or fracture zones but does not seem to have free means of escape into the subjacent limestone. As the water in the different veins is not in close communication, the level at which it occurs differs radically within short distances. Although the quantity of water is sufficient to be troublesome in mining operations, it is not great when compared with the dimensions of the underground workings. Mines that have been developed in igneous rocks representing lava flows generally lose their water by downward percolation when they are sunk into underlying limestone.

## DOMESTIC AND INDUSTRIAL SUPPLIES.

To obtain enough water for domestic and industrial supplies the meager sources of this area have been heavily drawn upon and one source entirely extraneous to the area has been called into requisition.

The large wells in the Homansville Basin and in the upper part of Eureka supply a number of the principal mines, the Rio Grande Western Railroad, and much of the water for domestic consumption in Eureka, and small private wells in the city are also used for domestic purposes. The water from springs whose flow has already been discussed is conducted through a pipe line, by gravity, to this region, where it supplies the domestic consumption of Silver City and also a smelter and several mines.

On the west flank of the West Tintic Mountains, about 20 miles from Mammoth, there is a pumping plant that lifts water from Cherry Creek to the summit of the range. From the summit the water is conducted, through a pipe line, across Tintic Valley to Robinson, where a second pumping plant is used in raising a part of the water to the higher levels of Mammoth and some of the mines. It is estimated that about 150,000 gallons are pumped daily at Cherry Creek. The water thus obtained provides the railway supply at Tintic Junction, the domestic supplies at Robinson and Mammoth, and the supplies for several of the mines. The water is reported to be somewhat hard but otherwise of good quality.

## PAVANT VALLEY.

### TOPOGRAPHY.

The Pavant Range extends along the southeastern border of Millard County and forms a continuous mountain tract nearly 50 miles long, with its highest peaks rising 5,000 feet above the adjacent country, or 10,000 feet above the sea (Pl. I). It abounds in springs and streams and supports a forest of large trees. In ground plan the range is a crescent, one horn of which projects north and the other southwest. On its southeastern convex side is the valley of Sevier River, which follows a course roughly concentric with the crest of the range. In the concavity on the opposite side, this range shelters the agricultural settlements of Kanosh, Hatton, Meadow, Fillmore, and Holden, beyond which stretches the sterile desert of western Utah. Toward the north the range bifurcates into the main Pavant Range and the Valley Range, and between these two forks lies Round Valley. North of the pass to Scipio the Canyon Range constitutes a virtual continuation of the Pavant Range.

From the north end of Pavant Valley to beyond Kanosh extends a relatively smooth and featureless, yet somewhat dissected, alluvial slope, which descends gradually from the mountain borders and passes insensibly into the flat bottom lands. Its broad and even expanse is interrupted north of Fillmore by "Cedar Mountain" and "Bald Mountain," and west of Kanosh by two lava buttes. (See fig. 11.) When Lake Bonneville stood at its highest level this slope was partly submerged, and at the water's edge a shore line was cut that can be seen distinctly when the region is viewed from the west. This shore line lies between the 5,000-foot and 5,500-foot contours as shown on the map (fig. 11). It passes through Holden and Fillmore and a short distance back of Meadow and Kanosh. On the west the bottom lands are to a large extent hemmed in by various low mesas of volcanic origin, but to the northwest, between the

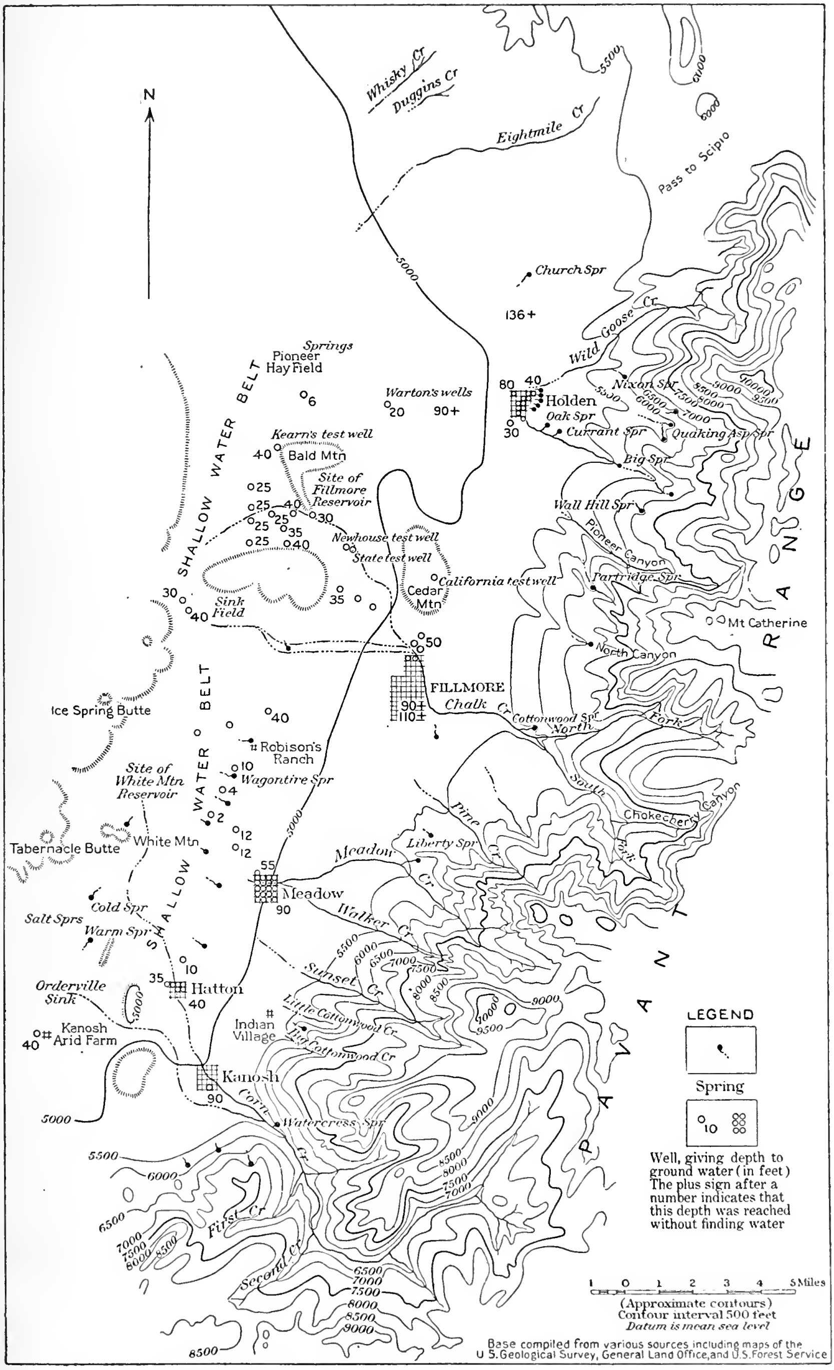



FIGURE 11.—Map of Pavant Valley, showing streams, springs, and ground-water conditions.

Canyon Range and Pavant Butte, they merge into the level expanse of Sevier Desert.

### GEOLOGY.

The rocks of this area include (1) quartzites and limestones, (2) conglomerates, sandstones and shales; (3) volcanic and intrusive rocks; and (4) unconsolidated stream and lake sediments. In age, the first are Paleozoic, the second Mesozoic and Tertiary, the third Tertiary, Pleistocene, and Recent, and the fourth chiefly late Tertiary and Pleistocene. The limestones and quartzites form the core of the Pavant Range from the north end to the westward projection southwest of Kanosh, and they are also exposed in ridges in the valley between Fillmore and Holden. After they had been deformed and eroded they were covered by the deposits that hardened into conglomerates, sandstones and shales, and that were later deformed and deeply eroded. At the south end of the range and in the mountains still farther south igneous rocks of Tertiary age occur in great quantity. In the desert to the west lavas and tuffs, ranging in age from Tertiary to very recent, lie at the surface in many localities, forming a chain of buttes and low mesas that partly isolate Pavant Valley from the main desert. Prominent among these buttes are Pavant Butte (locally known as Sugar-Loaf Mountain), Ice Spring Buttes, and Tabernacle Butte, all of which have been described in detail by G. K. Gilbert in his monograph on Lake Bonneville.

### RAINFALL.

Observations made at Fillmore for the United States Weather Bureau show that during a period of 17 years the annual precipitation has ranged from 9.32 inches (in 1900) to 21.28 inches (in 1906) (fig. 3), and has averaged 14.61 inches, of which 39 per cent has fallen in the spring months, but only 14 per cent in the summer months (fig. 4). The average precipitation is about the same as at Scipio and slightly less than at Levan, but nearly twice as great as at Deseret and Black Rock in the desert to the west. This difference in climate is reflected in the natural vegetation, for on the Pavant bench, as in Juab and Round valleys, large sagebrush flourishes, but farther west the brush has a more pronounced desert aspect. The Pavant Range, with its numerous streams and springs and its large timber, forms a striking contrast to the dry and barren Basin ranges.

Dry farming has been undertaken on a large scale west of Kanosh and on a smaller scale in other parts of the area, but at the time the region was visited (1908) it was uncertain whether this new enterprise would be successful.

*Precipitation (in inches) at Fillmore.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1892 | ...... | ...... | ...... | 2.11 | 2.03 | 0.82 | 0.29 | 0.47 | 0.06 | 1.07 | 0.53 | 1.20 | ...... |
| 1893 | 0.81 | 1.51 | 2.89 | 2.09 | 1.53 | .00 | .48 | 1.71 | 1.21 | .46 | 1.11 | 1.79 | 15.59 |
| 1894 | .70 | .56 | 1.04 | 2.43 | .64 | 2.04 | .34 | 1.19 | 1.94 | .41 | .31 | 1.77 | 13.37 |
| 1895 | 1.93 | 2.15 | 2.06 | 1.23 | 1.51 | .80 | .56 | .97 | 1.66 | .93 | 1.46 | 1.10 | 16.36 |
| 1896 | .75 | .16 | .94 | 1.47 | 1.06 | .01 | 2.36 | 1.69 | .85 | .37 | 1.17 | .33 | 11.16 |
| 1897 | 2.15 | 2.17 | 2.89 | 1.26 | .03 | .26 | .19 | .31 | 1.50 | 3.59 | 1.15 | 1.55 | 17.04 |
| 1898 | .15 | 1.20 | 3.07 | .59 | 4.44 | .96 | .99 | .06 | Tr. | .60 | 1.27 | .76 | 14.59 |
| 1899 | .50 | 1.40 | 5.00 | 1.45 | .85 | .96 | .01 | .28 | .00 | 1.94 | 1.06 | 1.03 | 14.48 |
| 1900 | 1.25 | .45 | .15 | 3.18 | .35 | .60 | Tr. | .14 | 1.58 | .93 | .66 | .03 | 9.32 |
| 1901 | .35 | 2.00 | 1.54 | 2.35 | 1.92 | .57 | .41 | .90 | .00 | .72 | .15 | 1.97 | 12.88 |
| 1902 | 1.03 | 1.03 | 2.59 | .36 | .90 | .09 | .49 | .16 | 1.51 | .58 | 2.70 | .46 | 11.90 |
| 1903 | 1.44 | 1.26 | 1.19 | 2.66 | 2.27 | .04 | .27 | .38 | 1.00 | 1.06 | .00 | .40 | 11.97 |
| 1904 | 1.89 | 1.90 | 2.16 | .26 | 2.81 | .25 | .07 | 1.13 | .10 | .62 | .00 | .95 | 12.14 |
| 1905 | .90 | 2.48 | 2.66 | 1.53 | 2.45 | Tr. | .53 | .62 | 2.81 | .51 | 1.13 | .54 | 16.16 |
| 1906 | .72 | 1.16 | 3.88 | 4.38 | 2.18 | .40 | 1.27 | 1.20 | 2.38 | .15 | 2.93 | .63 | 21.28 |
| 1907 | 1.67 | 1.96 | 1.34 | .55 | 3.20 | .88 | .97 | 1.23 | 1.24 | 1.99 | .25 | 1.86 | 17.14 |
| 1908 | 1.01 | .87 | .36 | .50 | 4.15 | 1.13 | 1.46 | 1.38 | 2.02 | 3.31 | .69 | 1.55 | 18.43 |
| Average | 1.15 | 1.39 | 2.11 | 1.67 | 1.90 | .58 | .63 | .81 | 1.17 | 1.13 | .98 | 1.05 | 14.61 |

## STREAMS AND MOUNTAIN SPRINGS.

The settlements at the west base of the Pavant Range are devoted almost exclusively to agriculture by means of irrigation, the water being derived, not from a single large source, but from a number of small streams that issue from the canyons and from numerous springs. (See fig. 11.) In general the flow of the streams is most copious in the spring when the snow in the mountains melts, but the discharge of any stream is likely to be temporarily greatly increased at any season by a heavy rainstorm in its small drainage basin. The normal flow is all carefully appropriated during the growing season, but as there are no reservoirs large amounts of water in times of flood and much of the winter flow passes the cultivated fields and reaches the bottom lands, where it is lost or produces a small amount of wild grass.

The largest streams are Corn Creek, which drains about 90 square miles and forms the principal irrigation supply for Kanosh and Hatton, and Chalk Creek, which drains scarcely 50 square miles but furnishes the main supply for Fillmore. At Meadow several small streams are relied upon (chiefly Meadow Creek, Walker Creek, and Sunset Creek), and at Holden several small streams (chiefly Wild Goose Creek and Pioneer Creek) and a number of large springs are utilized. A small amount of water issuing from the southwest flank of the Canyon Range is also used for irrigation.

## SHALLOW-WATER BELT.

Between the alluvial slope on the east and the lava fields on the west there is a belt of low level land in which the ground-water table is nearly at the surface. (See fig. 11.) Here there are many springs and seeps, and wells obtain water at only slight depths. Both the

northern section of this belt, which lies west of Holden and is in part known as the Pioneer Hay Field, and the southern section, which lies west of Fillmore and Meadow, support a growth of grass without artificial irrigation and furnish rather extensive hay fields and pastures. A chain of fresh-water springs, shown in figure 11, occurs along the east margin of this belt from west of Fillmore nearly to Hatton. Several miles northwest of Hatton, near the northeast corner of sec. 24, T. 22 S., R. 6 W., is the Warm Spring, from whose tuffaceous basin flows a copious stream of mineralized water with a temperature of 94° F. Several cold springs yielding mineralized water occur farther west and north in this locality.

Most of the water in the shallow-water belt is derived from the mountains east of this valley, but some seepage no doubt also comes from the table-lands to the west and from the sandy tracts. In addition to the supply from these underground sources the surface waters that are not diverted for irrigation accumulate in the low areas. The contributions from surface sources are greatest in the winter and early spring, but those from underground sources reach their maximum at a later season. The water level is usually highest and the yield of the springs greatest in the summer, following with some lag the thawing of the snow and the heavy rainfall of the spring months.

## ARTESIAN PROSPECTS.

Considerable attention has been directed toward the possibility of obtaining flowing water and several unsuccessful test wells have been drilled. One of these was sunk by the State of Utah, about 5 miles northwest of Fillmore (NW. ¼ sec. 36, T. 20 S., R. 5 W.), on low ground a short distance west of "Cedar Mountain." No definite record of this well is available. Its total depth is reported to be about 900 feet; the upper 100 feet are said to consist of clay and sand, below which the drill penetrated shale and red sandstone. Plentiful supplies of good water are said to have been found at the depths of 25 feet, 60 feet, and 80 feet, but there is less certainty as to the amount found in the rock strata. The water did not come to the surface, and that from the deeper sources barely rose to the level of the first ground water. As a small amount of oil was struck, three other wells were sunk by private enterprise. One of these is in the same locality and reached a depth of about 500 feet. Another, situated on the higher ground of "Cedar Mountain," reached a depth of 700 feet, but it is said to have found only a small quantity of water that stood 125 feet below the surface. The third well, situated at the northwest margin of "Bald Mountain" (sec. 15, T. 20 S., R. 5 W.), only

slightly above the level of the low flat, was carried to a depth of at least 1,800 feet, and seems to have penetrated quartzite for much of this distance. The drillers reported that water entered through crevices at different levels and that the quantity was rather great. The water stood about 40 feet below the surface and showed no tendency to rise as greater depths were reached. The location of these wells is shown in figure 11, page 87.

Throughout this region the structure of the rocks is not favorable for accumulating water under artesian pressure. Although in certain localities the strata dip toward the valley, this is not their general attitude, and the extensive fracturing and deformation do not give much reason for expecting flowing water.

In the shallow-water belt there were better prospects of obtaining flows from beds of sand in the unconsolidated sediments, but test wells have here also resulted in disappointment. Wells have been sunk in these sediments to depths of at least 190 feet. In some of them the water rose practically to the surface, but, as far as could be ascertained, no actual flow has anywhere been struck. The failure to obtain flows is probably to be attributed to the absence of a competent barrier on the west to confine the ground water and cause it to accumulate under pressure.

## WATER BENEATH THE BENCH LANDS.

Bordering the shallow-water belt on the east is a zone in which many wells have been sunk. In these wells the depth to water increases in general with the distance from the shallow-water belt. (See fig. 11.) The zone in which wells are successful coincides roughly with the zone in which the depth of water is less than 100 feet, but there is reason to believe that for some distance farther up the slope wells could be obtained by sinking to a somewhat greater depth. The water level is, however, likely to be higher near the settlements, where the large streams emerge from the mountains, than in the intermediate meagerly watered tracts.

The conditions in regard to the water table in the vicinity of Holden are the reverse of the conditions commonly found. This village is located at the base of a low cliff that marks the Bonneville shore line, several hundred feet above the bottom lands where the water table comes to the surface. At the foot of the cliff a number of springs emerge and wells find water at very shallow depths. Westward from the cliff the surface descends gently, yet the depth to water increases rapidly until in the northwestern corner of the village it is nearly or quite 100 feet, and 2 or 3 miles farther west

(N. ½ sec. 9, T. 20 S., R. 4 W.), and at a much lower level, there is a dry hole 90 feet deep. In figure 12 is shown the position of the cliff and springs, the location and depth to water of some of the wells, the slope of the surface, and the slope of the ground-water table, both of the latter being shown by contour lines with vertical intervals of 20 feet and referred to an arbitrary datum of 100 feet below the post office. The explanation of the conditions seems to be that a certain amount of underground seepage, instead of sinking at once to its normal level, follows along an impervious formation which comes near the surface at the foot of the cliff, but descends to greater depths toward the west.

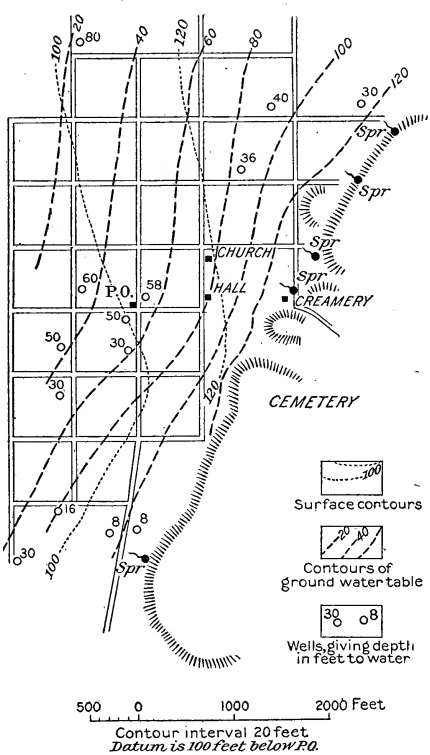



FIGURE 12.—Map of Holden, showing the relation of the ground-water table to the surface.

## QUALITY OF GROUND WATER.

In the following table are given two analyses of ground water from this area, both made at the Utah agricultural experiment station:

The first is an anaylsis of water from the well of Daniel Stevens on the NW. ¼ sec. 1, T. 21 S., R. 5 W., a few miles northwest of Fillmore; the well is 50 feet deep and has a normal depth to water of about 35 feet. As shown by the analysis the water contains only moderate amounts of the ordinary mineral substances, in which respect it is probably more or less typical of the water derived from most of the wells in this area and also of that from the springs along the east margin of the shallow-water belt.

The second is an analysis of water from the well on the Kanosh Arid Farm, in the NE. ¼ sec. 16, T. 23 S., R. 6 W., on low level ground several miles west of the village of Kanosh. This well is 42 feet deep, normally contains 4 or 5 feet of water and has yielded as much as 2,800 gallons in a day, or 400 gallons in a period of 30 minutes. The analysis shows that the water is rather highly mineralized, about one-half of its dissolved solid content apparently be-

ing common salt. In the region north of this well there are several springs, including the Warm Spring, that yield mineralized water.

*Analyses of ground waters in Pavant Valley.*

[Parts per million. Analyst, J. E. Greaves.]

| | D. Stevens's well. | Well on Kanosh Arid Farm. |
|---|---|---|
| Total solids | 520 | 2,220 |
| Silica ($SiO_2$) | 29 | 30 |
| Iron (Fe) | Trace. | Trace. |
| Calcium (Ca) | 38 | 73 |
| Carbonates, stated as calcium carbonate ($CaCO_3$) | 258 | 714 |
| Sulphate radicle ($SO_4$) | 2 | 294 |
| Chlorides, stated as sodium chloride (NaCl) | 89 | 1,181 |

### IRRIGATION WITH GROUND WATER.

Though flowing water may yet be obtained from wells sunk in unconsolidated sediments in the low-lying bottom lands, it is not probable that such wells would be of much consequence for irrigation because the pressure would probably be so weak that the yield would be small and the water would rise only to the surface of the low ground that is ill adapted for agriculture.

A few years ago an attempt was made by Edgar Warton to irrigate on his land, 4 miles west of Holden (S. ½ sec. 6, T. 20 S., R. 4 W.; see fig. 11), by pumping from wells of large diameter dug to a depth of about 40 feet. The power was at first applied by windmills but a gasoline engine was later installed. At the time the region was visited this project had been abandoned but no definite information was obtained as to the difficulties encountered.

Notwithstanding this apparent failure, it seems probable that a certain amount of irrigation could be successfully accomplished by pumping ground water. There is little doubt that a large supply of good water is available. The greatest danger of failure in this region lies in the alkali in the soil of the shallow-water tracts. In endeavoring to keep the vertical lift as low as possible there is danger of locating on land that is poorly drained and so impregnated with alkali that the project is predestined to failure. Perhaps the best use that can be made of the ground water in this valley, as in Juab Valley, is as a supplementary supply for the latter part of the growing season when the flow of the streams becomes small.

### CULINARY SUPPLIES.

In the village of Holden dug wells formerly furnished the domestic water supplies, but more recently there have been installed six small independent pipe lines leading from the springs at the foot of the

cliff along the east margin of the village (fig. 12), and most of the wells have accordingly fallen into disuse. The pressure in the pipes is not sufficient to afford fire protection.

In Fillmore several wells have been dug on comparatively low ground at the north end, but most of the people depend on the stream water. At the time the region was visited, plans were under consideration for the installation of a system of waterworks to be supplied by gravity from a mountain spring.

In Meadow and Hatton the domestic supplies are obtained chiefly from dug wells, which range in depth from about 55 to 90 feet in the former village and from about 30 to 40 feet in the latter.

In Kanosh the only well at present is that of Hyrum Prowse. This well was sunk to a depth of 127 feet and the water rises to a level 91 feet below the surface. It is reported to have been pumped for several hours at the rate of 15 gallons a minute. Two other wells were at one time dug but both have for some reason been abandoned. As in Fillmore, the domestic supply comes chiefly from the irrigation stream and is led to the houses through ditches, but plans are being considered to install waterworks that will be supplied from a spring.

## LOWER BEAVER VALLEY.

### TOPOGRAPHY AND GEOLOGY.

The Cricket Mountains, a typical basin range, on old maps called the Beaver Range, lie in the south-central part of Millard County and trend in a north-northeasterly direction. Farther south, in Beaver County, the range is continuous with mountains of another name, but at the north end it projects into a flat desert expanse. It is composed of paleozoic quartzites and limestones which for the most part dip toward the east, though in the vicinity of Goss they dip westward, giving this part of the range a synclinal structure. This range contains a few small springs, but it is essentially dry and barren, in which respect it is in strong contrast to the Pavant Range about 30 miles farther east.

The area between these two ranges consists of plains, mesas, and buttes. (See Pl. I.) The part lying south of a line extended westward from Kanosh is largely occupied by low mountains and table lands which are formed in part of stratified rocks and in part of igneous material, and into which the shore lines of the ancient Lake Bonneville have been incised. The part north of this line is occupied chiefly by a plain but contains a number of low tables and buttes of lava and tuff, a large part of which was extruded while the lake was in existence or since its desiccation. At the north end of the area is Pavant Butte (Sugar Loaf Mountain) whose exposed position and unique form make it a notable landmark.

Between the Beaver Range and the volcanic area just described, the valley of Beaver Creek leads northward from Beaver County and opens out upon Sevier Desert. (See Pl. I.) South of Black Rock the valley is broad, flat, and playa-like, but north of this station it becomes constricted between the mountain range and a lava plateau, and it is held within rather narrow limits until it reaches the vicinity of Turner's ranch, where the confining rock walls retreat or disappear. In the area between Cruz and Borden the valley is crossed by a succession of bars and terraces built during the Provo stage of Lake Bonneville, but farther north it expands into a low flat area that merges into Sevier Desert.

### RAINFALL.

Lower Beaver Valley and the adjacent uplands appear arid, barren, and desolate. The observations made at Black Rock for the United States Weather Bureau indicate an average annual precipitation of less than 10 inches.

*Precipitation (in inches) at Black Rock.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1901 | 0.40 | 1.43 | 0.34 | 1.29 | 0.78 | 0.94 | 0.15 | 1.02 | 0.00 | 0.56 | Tr. | 0.70 | 7.61 |
| 1902 | .26 | .20 | 1.15 | .16 | .23 | Tr. | .40 | .19 | .84 | .53 | 1.97 | .45 | 6.38 |
| 1903 | 1.11 | 1.30 | 2.00 | 2.59 | 1.72 | .33 | .41 | 1.75 | .92 | .95 | .10 | .18 | 13.36 |
| 1904 | 4.10 | 1.00 | .93 | .26 | 1.64 | .04 | .05 | .56 | .30 | .65 | .00 | .55 | 6.39 |
| 1905 | .48 | 2.26 | 1.74 | 1.28 | 1.52 | Tr. | .65 | .75 | 2.57 | .88 | | | |
| 1906 | 1.59 | | | 3.31 | .91 | .12 | | 1.12 | 2.33 | .03 | 2.11 | .97 | |
| 1907 | 1.85 | .78 | 1.50 | .52 | 1.31 | .53 | .04 | | | | | | |
| 1908 | | | | Tr. | 1.59 | .26 | 1.17 | .80 | | 3.31 | .60 | | |
| Average | | | | | | | | | | | | | 8.43 |

### STREAMS.

The valley of Beaver Creek forms the natural outlet for a large drainage basin that lies to the south of Lower Beaver Valley, and if the climate were more humid it would be occupied by a river; but under existing conditions the streams that rise in the high mountains of Beaver County normally disappear long before they reach this region, and it is only in exceptional freshets that water flows through this part of the valley. At Turner's ranch a reservoir for storing flood water has been built, the dam being at a point where an ancient lake bar is projected across the valley. Pine Creek, in the northeast corner of Beaver County, and Cove Creek, in the southeast corner of Millard County (Pl. I), have small irrigation supplies, but the channel that leads from these small streams to Beaver Creek is normally dry.

### SPRINGS.

#### BLACK ROCK SPRINGS.

In the vicinity of Black Rock station the eastern border of Beaver Valley is formed by the abrupt cliff of a large plateau. In a re-

entrant of this cliff, about 1 mile east and a short distance south of the station, there are three groups of springs that issue from crevices in the lava rock near the base of the cliff. The southernmost group yields the most water. Its flow, measured at different times by the railroad company, was found to average 622,000 gallons per day, or 432 gallons per minute, and to be nearly constant, the daily yield at no time being found to vary more than 10,000 gallons from the average. The water has a temperature of about 58°F. It is of good quality and contains only moderate amounts of the mineral substances usually found in ground waters. The following analyses of water from the south group are reported by the railroad company. No. 1 represents water from the small spring farthest north in this group; No. 2, water from the middle spring; and No. 3, water from the large spring farthest south.

*Analyses of water from Black Rock Springs.*

[Parts per million.[1] Analyst, Herman Harms.]

| | 1 | 2 | 3 |
|---|---|---|---|
| Total solids | 397 | 324 | 328 |
| Siliceous matter ($SiO_2$) | 48 | 49 | 50 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 2.5 | 1.5 | 2 |
| Calcium carbonate ($CaCO_3$) | 0 | 69 | 70 |
| Magnesium carbonate ($MgCO_3$) | 11 | 31 | 39 |
| Calcium sulphates ($CaSO_4$) | 62 | 27 | 28 |
| Sodium chloride ($NaCl$), magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), volatile, organic, and loss | 273 | 146 | 139 |

[1] Originally reported in grains per gallon.

A part of the water is led through a pipe line to the station, where it is used in the locomotives and forms the only domestic supply; the rest is used for irrigation on James's ranch, at the springs, where it produces a small oasis in the midst of a large desert.

### CLEAR LAKE SPRINGS.

Somewhat more than 30 miles northwest of Black Rock Springs is a group of springs that furnish a larger supply of water for irrigation. These springs are situated east of Clear Lake station and southwest of Pavant Butte, and issue from the margin of the lava bed that extends southward from that butte. They give rise to a small lake that was formerly called Spring Lake but is now locally known as Clear Lake, from which the water naturally discharges into a marshy area to the north but is at present led through a canal to Clear Lake station, where it is used with partial success for irrigation. The following analysis of water from the lake was made at the Utah agricultural experiment station.

*Analysis of water from Clear Lake.*

[Parts per million. Analyst, J. E. Greaves.]

| | |
|---|---|
| Total solids | 1,003 |
| Silica ($SiO_2$) | 19 |
| Iron (Fe) | Trace. |
| Calcium (Ca) | 77 |
| Carbonates, stated as calcium carbonate ($CaCO_3$) | 240 |
| Sulphate radicle ($SO_4$) | 188 |
| Chlorides, stated as sodium chloride (NaCl) | 786 |

### OTHER SPRINGS.

These two large springs, or rather groups of springs, both closely related to beds of volcanic rock, are the only ones in the area that yield water in sufficient quantity for irrigation, but several smaller springs are valuable as desert watering places. Among these are Antelope Spring, about 7 miles southeast of Black Rock, the Coyote Springs, about the same distance northeast of Black Rock, and a small spring north of North Twin Butte. There are also several springs in the mountains southwest of Black Rock and one small spring, known as Cricket Spring, on the west side of the Cricket Mountains.

## WELLS.

### WELLS ON THE BEAVER BOTTOMS.

Between Black Rock and Milford, Beaver Valley constitutes a low flat area, known as the Beaver Bottoms, in which ground water occurs near the surface. Here a number of wells have been dug or drilled, and some of these wells overflow, but the water-bearing sediments are fine, the yield is small, and the water is generally saline. Most of the wells are in Beaver County and have been discussed in the report on that region.[1]

### GOSS WELL.

The railway well at Goss is reported to be 1,775 feet deep and to end in granite. According to the section, which is shown in Plate III and is given in detail in the following table, the material from the surface to a depth of 355 feet consists of clay or shale except at three horizons where sand or gravel occurs, and between the depths of 355 feet and 1,584 feet it consists almost exclusively of clay or shale. Salty water was obtained at depths of 195 feet and 350 feet. The yield from the first horizon was about 1 gallon per minute, and from the second about 14 gallons per minute. Near the bottom large supplies were found, but the water, like that at higher horizons, is salty. When 10-inch casing had been inserted to a depth of 1,555 feet the well is reported to have been pumped with

[1] Lee, W. T., Water resources of Beaver Valley, Utah; Water-Supply Paper U. S. Geol. Survey No. 217, 1908, p. 30.

a Sillett deep-well cable pump extending to a depth of 410 feet for 15 hours continuously at a good many hundred gallons a minute without depleting the supply. Pumping at about 75 gallons per minute was continued for over a year in the hope that the quality of the water would be improved, but, as far as was ascertained, no improvement took place. So great, however, is the need for a supply at this point that the water, bad though it is, is used to some extent in locomotive boilers.

*Section of railroad well at Goss.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Clay | 12 | 12 |
| Clay and gravel | 25 | 37 |
| Sticky blue clay | 32 | 69 |
| lay | 118 | 187 |
| Blue waxy clay and brown sedimentary sand (salty water at 195 feet; 1 gallon per minute) | 15 | 202 |
| Blue clay | 24 | 226 |
| Blue clay and shale | 18 | 244 |
| Blue shale | 60 | 304 |
| Blue clay | 46 | 350 |
| Fine sand (salty water; 14 gallons per minute; analysis given below) | 5 | 355 |
| Gray shale | 59 | 414 |
| Soapstone | 238 | 652 |
| Brown waxy clay | 96 | 748 |
| White clay | 15 | 763 |
| Hard blue clay | 93 | 856 |
| Hard soapstone | 17 | 873 |
| Blue clay | 347 | 1,220 |
| Silt shale | 42 | 1,262 |
| Brown clay | 38 | 1,300 |
| Brown clay and rock | 12 | 1,312 |
| Rock | 10 | 1,322 |
| Sedimentary stone | 12 | 1,334 |
| Silt shale | 48 | 1,382 |
| Shale | 49 | 1,431 |
| Soapstone | 83 | 1,514 |
| Soapstone and bowlders | 26 | 1,540 |
| Soapstone | 44 | 1,584 |
| Cemented gravel | 17 | 1,601 |
| Blue limestone | 4 | 1,605 |
| Cemented gravel | 5 | 1,610 |
| Blue limestone | 22 | 1,632 |
| Blue limestone and yellow clay mixed | 11 | 1,643 |
| Granite (a soft streak between 1,770 and 1,773 feet is supposed to be the source of the large supply of water; analysis given below) | 132 | 1,775 |

*Analyses of water from the Goss railroad well.*

[Parts per million.[1] Analyst, Herman Harms.]

| | Sample from depth of 350 feet, July 25, 1906. | Sample from completed well, Oct. 12, 1907. |
|---|---|---|
| Total solids | 5,114 | 3,333 |
| Siliceous matter ($SiO_2$) | 25 | 23 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 5 | 17 |
| Calcium carbonate ($CaCO_3$) | 51 | 71 |
| Calcium sulphate ($CaSO_4$) | Trace. | 125 |
| Magnesium carbonate ($MgCO_3$) | 34 | 42 |
| Sodium chloride (NaCl) | 3,063 | 2,195 |
| Sodium sulphate ($Na_2SO_4$), magnesium sulphate ($MgSO_4$), sodium bicarbonate ($Na_2CO_3$), volatile, organic, undetermined, and loss | 1,936 | 860 |

[1] Originally reported in grains per gallon.

### NEELS WELL.

The railway well at Neels, which is 1,998 feet deep, resembles the Goss well in that it passes through great thicknesses of clay or shale and ends in granite. (See Pl. III and the log given below.) The proportion of coarser sediments is, however, somewhat greater, and water was reported at no less than nine horizons. Six-inch casing was inserted to a depth of 1,425 feet. The largest supplies of water come from the thick beds of gravel and sandstone that occur at about this level, and it is reported that no water was found in the formations below these. W. T. Lee[1] states that the well was pumped at 260 to 300 gallons per minute during a test lasting continuously for 24 hours; H. C. Sillett, who has more recently tested the well for the railroad company, reports that with his deep-well cable pump, in which he used the entire 6-inch casing as the pump-cylinder, he was able to draw water at the remarkable rate of about 2,000 gallons per minute. The water from all horizons is salty. In three analyses reported by Mr. Lee, the chlorine content is, respectively, 1,065 parts, 1,063 parts, and 863 parts per million, and the total solids are 3,336 parts, 3,345 parts, and 2,888 parts per million. Beds of lava and volcanic ash occur at different depths, and the water that comes from the deep sources is hot. As in the Goss well, it was hoped that heavy and long continued pumping might improve the quality, but this hope was not realized. The well has now been abandoned.

*Section of railroad well at Neels.*[2]

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Surface soil | 4 | 4 |
| Sedimentary (alkali) | 5 | 9 |
| Fire clay | 40 | 49 |
| Water-bearing quicksand | 9 | 58 |
| Shale and soapstone | 21 | 79 |
| Rock (sedimentary) | 6 | 85 |
| Water-bearing quicksand | 3 | 88 |
| Soapstone | 11 | 99 |
| Soapstone with fossil bowlders | 39 | 138 |
| Water-bearing quicksand | 4 | 142 |
| Fire clay | 12 | 154 |
| Blue waxy clay | 34 | 188 |
| Gray shale and clay mixed | 7 | 195 |
| Gray waxy clay | 36 | 231 |
| Lava rock | 12 | 243 |
| Blue waxy clay | 12 | 255 |
| Sedimentary sandstone | 6 | 261 |
| Blue waxy clay | 25 | 286 |
| Water-bearing quicksand | 6 | 292 |
| Blue waxy clay | 28 | 320 |
| Water-bearing quicksand | 7 | 327 |
| Sedimentary sandstone | 10 | 337 |
| Yellow clay | 16 | 353 |
| Water-bearing quicksand | 5 | 358 |
| Yellow clay | 27 | 385 |
| Blue waxy clay | 110 | 495 |
| Yellow clay | 15 | 510 |
| Sedimentary sandstone | 24 | 534 |
| Blue waxy clay | 17 | 551 |

[1] Water-Supply Paper U. S. Geol. Survey No. 217, 1908. [2] Idem, p. 33.

*Section of railroad well at Neels*—Continued.

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Soapstone | 50 | 601 |
| Blue waxy clay | 11 | 612 |
| Silt | 8 | 620 |
| Water-bearing quicksand | 3 | 623 |
| Yellow clay | 53 | 676 |
| Sedimentary sandstone | 12 | 688 |
| Yellow clay | 34 | 722 |
| Blue waxy clay | 117 | 839 |
| Yellow clay | 9 | 848 |
| Blue waxy clay | 210 | 1,058 |
| Blue shale (sand mixed) | 18 | 1,076 |
| Blue waxy clay | 13 | 1,089 |
| Blue shale | 45 | 1,134 |
| Blue shale (sand mixed); yielded hot water | 71 | 1,205 |
| Red shale | 12 | 1,217 |
| Blue shale | 70 | 1,287 |
| Red shale | 24 | 1,311 |
| Blue shale | 28 | 1,339 |
| Red "keel" stone | 6 | 1,345 |
| Water, sand, gravel, and bowlders | 70 | 1,415 |
| Sedimentary sandstone, brown | 35 | 1,450 |
| Red sandstone | 95 | 1,545 |
| Red shale, burned | 35 | 1,580 |
| Trap rock, dark brown | 36 | 1,616 |
| Red shale, burned | 56 | 1,672 |
| Lava rock with calcite crystals | 14 | 1,686 |
| Red sandstone | 68 | 1,754 |
| Red clay, sticky | 48 | 1,802 |
| Volcanic deposit, ash, and bowlders; gas under pressure sufficient to raise 6,200 pounds of tools 400 feet | 105 | 1,907 |
| Bowlders, cemented | 6 | 1,913 |
| Cavity | 9 | 1,922 |
| Bowlders | 22 | 1,944 |
| Cavity | 6 | 1,950 |
| Granite with crevices and gas | 48 | 1,998 |

### CLEAR LAKE WELL.

At Clear Lake station a well was at one time drilled by the railway company, but it has long since been abandoned, and the data in regard to it are accordingly vague. Its depth was variously reported at 1,335 and 1,380 feet. Water was struck at several depths. According to some accounts the water overflowed with slight pressure, but according to others it remained 4 feet below the surface. No water flows from the well at present. The water was used for a number of years, but was too highly mineralized to be satisfactory for steam making, and the bad quality appears to be the reason for the disuse of the well. At present the culinary supply for Clear Lake is hauled from Oasis by the railroad company.

### SWAN LAKE FARM WELLS.

On the Swan Lake farm (sec. 15, T. 19 S., R. 9 W.), about 6 miles west of Clear Lake, there is an old flowing well which is said to be about 600 feet deep and which yields a small amount of water. The water has a distinct taste and in a rough field test was found to contain about 500 parts per million of chlorine. The water is used at the ranch for culinary purposes.

In a well drilled 4 miles farther west, at the headquarters of the Swan Lake farm (about sec. 13, T. 19 S., R. 10 W.), the strata penetrated were chiefly clay, but a number of sandy water-bearing beds were found, all of which yielded salty water and none of which gave rise to a flow. The drilling was carried to 365 feet below the surface, at which depth the hole was abandoned.

*Section of abandoned well on the Swan Lake farm.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Clay | 48 | 48 |
| Gravel (very salty water which stood 10 feet below the surface) | 7 | 55 |
| Hardpan with thin layers of sand (salty water) | 65 | 120 |
| Soft light-blue clay | 15 | 135 |
| Light-colored hardpan with 7 strata of sand, each 4 to 6 inches thick (small yield of salty water, which stood 17 feet below the surface) | 230 | 365 |

### SHALLOW WELLS IN THE VALLEY BELOW BLACK ROCK.

For some distance north of Black Rock the valley is narrow and there is no evidence of ground water. At Turner's ranch, where the surface water is to some extent entrapped between bars built by the ancient lake, there is a shallow dug well. On the low flat farther north the ground is generally saturated, especially in the vicinity of irrigated fields, and in many places seepages of poor water can be obtained near the surface.

## OLD RIVER BED AND CHERRY CREEK REGION.

### GENERAL FEATURES.

Sevier Desert is inclosed on the north by a group of ranges which includes the Champlin, West Tintic, Simpson, McDowell, and Drum mountains. South of the Simpson Mountains lies a rugged area that culminates in a cluster of bald peaks known locally as Desert Mountain, and south of the McDowell Mountains is a lava plateau which is bounded by precipitous walls and which stands prominently above the adjoining plain. (See Pl. I.) The low, flat area of Sevier Desert extends to the region east of this plateau, and farther north contracts into a narrow belt through which passes the Old River Bed. This constricted valley leads between the McDowell Mountains on one side and the Desert and Simpson mountains on the other, to Tooele County and the flat expanse surrounding Great Salt Lake. (See Pl. I.)

Broad open plains extend from the low flat and the Old River Bed into the largest reentrants between the mountains, their surfaces rising gently but continuously toward the mountain borders where

they have an elevation several hundred feet above the low flat or the Old River Bed. One of these amphitheaters extends between Desert Mountain and Simpson Mountains and opens to the Old River Bed. It has no recognized name, but as Judd Creek enters it from the north it can properly be designated Judd Creek Valley. A larger plain of the same character, sometimes called Cherry Creek Valley after the stream that flows into it, lies in the angle between Desert Mountain and the West Tintic and Champlin mountains, and leads out upon the low, marshy tract east of the lava bed. A third large valley lies between the McDowell Mountains, on the east, and the Thomas and Drum ranges, on the west, and leads southeastward to the Sevier Desert flat.

When Lake Bonneville stood at its highest level its waters covered the low flat and the Old River Bed to a depth of 600 to 700 feet, and inundated the sandy bench to the east and the lower parts of all the principal valleys. Cherry Creek Valley and Judd Creek Valley were then bays, and the site of Rockwell's ranch was under water. Desert Mountain formed a rocky promontory connected with the mainland by an isthmus that extended between the bays just mentioned. The McDowell Mountains were completely surrounded by water and the numerous small buttes to the north formed an archipelago of rocky islands. The lava plateau was entirely submerged except for Fumarole Butte, commonly known as "the crater," and a small butte farther northeast. (See fig. 2.)

In the Provo stage the lake covered the low flat and Old River Bed and reached some distance up the central axes of Cherry Creek and Judd Creek valleys, but the lava plateau and the valley to the west were dry land, as is indicated in figure 2. Both the Bonneville and Provo shore lines are marked by beach ridges, terraces, and sea cliffs, and form easily recognized natural datum planes which assist in estimating the altitude and probable depth to water in any given locality. At a later stage, when the lake level was lowered still more, a stream flowed northward through the Old River Bed, as is described by Mr. Gilbert in his monograph on Lake Bonneville.

The relation of the vegetation to the shore lines is significant. In some places shad scale predominates above the Provo shore line and greasewood below it. Owing to the seepage from the large gravel terraces, the vegetation at the foot of these terraces is more luxuriant than it is elsewhere, and greasewood and rabbit brush are dominant. Large sagebrush is found along arroyos through which freshets occasionally discharge, the soil here containing less alkali than in the low areas and receiving more moisture than in other parts of the bench lands.

### WATER SUPPLIES.

The principal water supply in this region is furnished by Cherry Creek, which rises in the West Tintic Mountains and flows southwestward, as shown in Plate I. Upon this creek depends Rockwell's ranch (NE. ¼ sec. 30, T. 12 S., R. 5 W.), the so-called Company ranch (SW. ¼ sec. 10, in the same township), and the pumping station (about 5 miles farther northeast), from which a pipe line leads to the Tintic mining district, 20 miles distant. Approximately 150,000 gallons of water is pumped daily from Cherry Creek into Tintic Valley. Only enough water reaches the two ranches to supply the live stock and to irrigate small plats of land.

This region contains a few other small mountain streams, among which may be mentioned Judd Creek, on the south flank of the Simpson Mountains, and a few isolated mountain springs, such as Keg Spring, on the north slope of the McDowell Mountains. None of these furnish much water, but they are valuable as watering places for live stock on the range.

The only other source of water in this region is the Hot Springs situated at the east base of the lava plateau, where hot water issues in large quantities from mounds of variegated hues and gives rise to columns of vapor which, on favorable days, can be seen far out on the desert. Temperatures ranging from 110° to 178° F. were observed by Mr. Gilbert.[1] Certain types of red, yellow, and green algæ live in the hot water and are largely responsible for the bright colors that characterize the locality. The water is strongly saline, the amount of chlorine found in a field test being about 1,600 parts per million. The combined yield from the different openings amounts to several hundred gallons per minute. The water flows unused to the swampy area east of the springs, but on its way, where sufficiently cooled, it produces a meager growth of poor grass. The large quantities of salt in the water and soil of the vicinity prevent the successful use of the water for irrigation. These springs probably owe their origin to fissures in the lava bed and derive their high temperature from the residual heat retained by the lava at some depth below the surface.

### GROUND-WATER PROSPECTS.

Owing to the lack of irrigation supplies and of other resources, this region remains almost without permanent inhabitants, and hence there has been little incentive to dig or drill for ground water. Nevertheless in certain sections wells yielding good water could probably be obtained by moderately deep wells.

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[1] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890, p. 333.

Surrounding the Champlin Mountains and reaching to the foot of the West Tintic Range there is an extensive upland area, much of which is deeply buried in sand. Part of the water that falls as rain on this area sinks into the ground and is probably transmitted to beds of sand and gravel underlying Cherry Creek valley and the low belt of land that extends southward toward the Desert Wells. Much of the run-off from the west slope of the West Tintic Range sinks into the gravelly materials at its margin and is also added to the ground water below the valley. There are, therefore, rather good prospects for obtaining successful wells in the region that lies in general southwest of Rockwell's ranch, and the water that is found will probably be of good quality. However, it is not likely that the ground water stands greatly above the level of the low flat east of the lava plateau, and hence it is only on the lower parts of the slopes from the uplands that the prospects are good for getting water at moderate depths. In the low flat east of the lava plateau the ground-water level is near the surface and flows might possibly be obtained, but there is some danger that the sediments are here too fine to yield water freely or that the water is saline. The alkali in the soil and the poor drainage of the flat are unfavorable for irrigation with ground water even if satisfactory supplies could be developed.

In the valley north of Desert Mountain, here called Judd Creek valley, the conditions are comparable to those in Cherry Creek valley. This valley receives a supply of ground water from the mountainous areas that border it on the north, east, and south, and the water is likely to be of good quality. Both the Bonneville and Provo shore lines are plainly traced upon the great amphitheater that comprises this valley; the Bonneville near the top and the Provo near the bottom. Below the Provo shore line there are prospects for obtaining successful wells at moderate depths.

In that part of the Old River Bed that lies east of the McDowell Mountains there are no indications that the ground water comes to the surface, but the low altitude makes it probable that the ground-water level is within reach of ordinary drilling operations, and there are fairly good chances of obtaining successful wells along the site of this ancient stream channel. Mr. Gilbert's monograph on Lake Bonneville mentions an abandoned well, 100 feet deep, at the old stage station in the River Bed, a short distance beyond the north boundary of Juab County.

## DRUM AND SWASEY WASH REGION.

### WELLS AT JOY.

In a pass through the Drum Mountains are located the Joy post office and Laird ranch, and near by is the Ibex mine, where a few

miners are at work. This small settlement contains the only permanent human inhabitants that will be found in going from Fish Springs to the settlements in Sevier Desert, or from Trout Creek, in Snake Valley, to Rockwell's ranch, on Cherry Creek. Here are two small but highly prized water supplies. One is at the ranch and comes from a tunnel and other shallow excavations. The other, about a mile farther northwest, is obtained from a well 30 feet deep, and is used by the freighters who operate between Fish Springs and Oasis, and also by the men at the Ibex mine. (See Pl. IV.) The conditions are here similar to those in the Tintic mining district. Where the porous rock waste has not been removed by erosion it collects rain water, and as this water can not penetrate the underlying firm igneous rock it forms seeps that can be tapped at favorable points. Evidently the best localities to prospect for supplies of this kind are where igneous rock occurs and where there is some indication of seepage at the surface. As in the Tintic district, the supply fluctuates with the rainfall, but, as far as is known, the wells have at no time dried up completely.

### OTHER WATER SUPPLIES.

The barren and desolate region that surrounds Joy for many miles in all directions is nearly destitute of springs, wells, or water supplies of any kind. The Hot Springs, to the east, and Keg Spring, far to the northeast, have been mentioned in describing the Old River Bed region (pp. 101–104); Wild Horse Spring is 15 miles northwest of Joy, in the Thomas Range; Swasey Spring is 15 miles southwest of Joy, at the east margin of the House Range; Antelope Spring is 5 miles farther southwest, near the summit of this range; and a spring in Granite Canyon is 15 miles still farther south, in the same range. (See Pl. IV.) In the area that lies between Fish Springs flat and White Valley on the west and the Old River Bed and Sevier River on the east these are the only springs worthy of mention.

A prospector is reported to have struck water at a depth of 30 feet about 6 miles south of Joy, the conditions probably being similar to those at Joy. At the site of an abandoned smelter midway between Joy and Deseret, on the road that leads between Drum and Little Drum mountains, there is a well that consists of a hole dug to the depth of 90 feet and drilled with 1½-inch casing from this level to a total depth of 190 feet. The water rises through the casing and fills the dug hole to a level about 80 feet below the surface. The water is reported to be of good quality, but the yield is not large. This well, which is known as the Old Smelter well, forms one of the watering places for the freighters who haul ore from Fish Springs to Oasis.

### GROUND-WATER PROSPECTS.

A large valley lies between the Drum and McDowell mountains and leads southeastward to Sevier Desert; a smaller valley lies between the Drum and Little Drum mountains and likewise leads to Sevier Desert; and a large open valley, commonly known as Swasey Wash, intervenes between the Little Drum Mountains and the House Range and leads in the same direction. All three of these valleys lie at considerable elevations above the ground-water level of Sevier Desert and their axes have pronounced gradients. They are therefore probably drained of their ground water to great depths.

The strata of the House Range form an eastward dipping monocline. On the west their edges are exposed and form an imposing escarpment overlooking White Valley; toward the east they gradually pass beneath alluvial and lake sediments. The débris-covered slope that extends from this range to the flat of Sevier Desert is remarkably wide and has a total descent of nearly 1,000 feet. There can be little doubt that the width of the slope is largely due to the underlying eastward-dipping rock strata. The prospects are not good for finding water below this slope. The unconsolidated sediments are likely to be drained, and the limestone and quartzites, which lie below them in a large part of the area, are unpromising as sources of water.

Successful wells may possibly be sunk at the foot of the slope that descends from the House Range and in the areas where the valleys mentioned above merge into the low flat of Sevier Desert. Here the ground-water level is likely to be within reach of the drill and coarse sediments containing fresh water probably exist. On the flat farther east there is more danger of encountering only fine lake sediments, which may not yield freely and whose water may be saline.

## SEVIER DESERT.

### PHYSIOGRAPHY.

Sevier River, the only large stream that enters the region discussed in this report, follows a devious course. Rising in the high plateau near the south boundary of the State it flows northward for nearly 150 miles in a structural trough, then turns and passes through Little Valley and Sevier Canyon, from which it emerges at Leamington; thence it flows southwestward through Sevier Desert and discharges into the alkaline waters of the playa-like lake that bears its name. (See Pl. I.)

Like the numerous smaller streams of this region Sevier River has built an alluvial fan where it debouches from the mountains, though, in accordance with its greater volume of water, its fan is more ex-

panded and has a gentler grade. When Sevier Desert was submerged beneath Lake Bonneville, the river deposits were built into a delta rather than into a fan, and thus a somewhat complex structure has resulted. In the Bonneville stage the lake level was so high that Little Valley contained a land-locked bay and Sevier Canyon became a strait (fig. 2), and under these conditions the bulk of the stream's load came to repose before reaching the Leamington area. In the Provo stage, which lasted for a long time, the water stood at a level more favorable for building a delta below the canyon.

Sevier Desert may be regarded as consisting of two plains at different levels, the ascent from one to the other being steep enough to form a recognized topographic feature. The upper plain, commonly known as the Lynn bench, is essentially the ancient delta of Sevier River. It occupies the region on both sides of the river as far downstream as the vicinity of Burtner. Here its margin swings back, on one side trending southeast toward the south end of the Canyon Range and on the other side trending somewhat east of north in the direction of Rockwell's ranch. The altitude of this delta plain is approximately that of the Provo shore line, being 4,790 feet above sea level at Lynn, 4,785 feet at Cline, and about 4,770 feet at the Burtner Dam. Since the subsidence of the lake Sevier River has carved a gorgelike valley out of the loose sediments of the delta. At the Burtner Dam the valley has two terraces, one about 20 feet below the upland, and the other about 75 feet lower, or about 40 feet above the present flood plain. The sides of the valley have the castellated appearance of badlands. The walls bordering the present flood plain are conspicuously steeper and more angular than those bordering the terraces.

In the vicinity of Burtner, the river leaves its gorge and flows out upon the extensive low flat that forms the lower plain of Sevier Desert. A few miles farther downstream its valley disappears entirely and it occupies a channel whose banks are on a level with the general surface of the plain or slightly higher. Here the stream is of the aggrading type and frequently changes its course, as is attested by many channels that meander over the plain and in many places form low ridges. In times of high water large portions of this lower plain are inundated and are converted into impassable swamps. Sevier Lake, however, lies at a lower level, and before reaching it the river occupies a definite though shallow valley.

Sevier Desert is nearly surrounded by mountain ranges. The Canyon, Pavant, Beaver, Drum, McDowell, Desert, West Tintic, and Champlin ranges all form parts of the inclosing rock wall, and where gaps occur between these ranges other mountains rise in the background. In contrast to the great relief and the rugged topography

of the mountains, which are always in sight, the vast expanse of Sevier Desert appears flat and featureless and the difference in level between the Lynn bench and the lower plain is inconspicuous. The impression of flatness is heightened through the contrast afforded by the isolated volcanic buttes and mesas which here and there rise abruptly above the floor of the desert. The Lynn bench and the alluvial slopes adjoining the mountains give the desert a total relief of several hundred feet, the gorge in the Lynn bench is locally a conspicuous feature, and the sand dunes and abandoned stream channels break to some extent the monotony of the general surface.

## RAINFALL.

Records of precipitation at Deseret and Oak City are presented in the following table. In the 11 years for which the record at Deseret is complete, the annual precipitation ranged between 4.85 and 11.77 inches, and averaged 8.15 inches, which is approximately the same as at Black Rock and Frisco, but is only one-half as much as at Levan and also substantially less than at Scipio, Fillmore, and Oak City. (See p. 19 and fig. 3.) As at other stations in this section of the country, the most rain falls in the spring and the least in the summer. (See fig. 4.) In an average year the precipitation at Deseret during the months of June, July, and August together is only about 1 inch.

*Precipitation (in inches) at Deseret.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1891 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0.64 | 0.62 | 0.05 | 0.00 | 0.21 | ...... |
| 1892 | 0.53 | 1.30 | 1.84 | 0.71 | 1.81 | 0.14 | 0.42 | .58 | .06 | 1.12 | .10 | .86 | 9.47 |
| 1893 | .54 | .61 | 1.85 | 1.40 | .67 | .00 | .21 | .91 | .46 | .05 | .14 | .82 | 7.66 |
| 1894 | .35 | 1.35 | .53 | .64 | .43 | 1.29 | .25 | .23 | 1.67 | .39 | .00 | .88 | 8.01 |
| 1895 | .40 | .53 | .63 | .84 | ...... | Tr. | Tr. | Tr. | .80 | .45 | .84 | .38 | ...... |
| 1896 | .32 | ...... | .29 | .47 | ...... | | | | | | | | ...... |
| 1899 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | Tr. | 1.23 | .34 | .80 | ...... |
| 1900 | .36 | .05 | Tr. | 2.85 | .10 | .03 | Tr. | Tr. | 1.12 | .39 | .48 | .00 | 5.38 |
| 1901 | .10 | 1.67 | .80 | 1.02 | 1.90 | .62 | .03 | 1.54 | .03 | .50 | .04 | .76 | 9.01 |
| 1902 | .48 | .30 | .82 | .36 | .32 | Tr. | .08 | .04 | .40 | .20 | 1.65 | .20 | 4.85 |
| 1903 | .94 | 1.30 | .40 | .90 | 1.53 | .40 | Tr. | .08 | .67 | .72 | Tr. | .05 | 6.99 |
| 1904 | .15 | .97 | 1.55 | .13 | 2.13 | .60 | Tr. | .20 | .32 | .32 | .00 | .77 | 7.14 |
| 1905 | .42 | 1.25 | 1.06 | 1.36 | 1.35 | .00 | .00 | 1.15 | 1.79 | Tr. | 1.25 | .13 | 9.76 |
| 1906 | .31 | .41 | 2.10 | 1.63 | 1.06 | .19 | ...... | .63 | .95 | Tr. | 1.38 | .94 | 11.77 |
| 1907 | 1.66 | .82 | 1.00 | .10 | 2.20 | 1.07 | .04 | .29 | .87 | .60 | .20 | .79 | 9.64 |
| 1908 | .11 | .80 | 1.00 | .40 | 1.10 | 1.22 | ...... | .57 | 2.00 | 2.15 | .25 | .34 | ...... |
| Average | .48 | .87 | 1.07 | .91 | 1.22 | .43 | .10 | .49 | .78 | .55 | .45 | .53 | 8.15 |

*Precipitation (in inches) at Oak City.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1905 | ...... | ...... | 1.83 | 1.30 | 1.91 | 0.00 | 0.15 | 0.63 | 2.29 | 0.15 | 1.55 | .54 | ...... |
| 1906 | 1.09 | 0.91 | 3.49 | 3.28 | 2.31 | .58 | .83 | 1.56 | .94 | .27 | 2.15 | 1.64 | 19.05 |
| 1907 | 1.80 | 1.80 | 1.47 | .69 | 1.69 | 1.37 | 1.04 | 1.15 | .91 | .69 | .12 | 1.51 | 14.24 |
| 1908 | .66 | .71 | 1.15 | .57 | 3.29 | .59 | .56 | .87 | 2.34 | 2.55 | ...... | .86 | ...... |

## GROUND-WATER LEVEL.

Much of the water that falls as rain on the mountains and elevated valleys that encircle Sevier Desert migrates, either in surface streams or by underground percolation, toward the low interior. Thus, though in the high areas the ground water is at great depths or may be entirely drained away, in the low interior it has accumulated until it is practically at the surface. The lowest depression is that occupied by Sevier Lake, but the entire Sevier Desert except at Lynn bench and the alluvial slopes near the mountains is so nearly at a level that the ground water is everywhere near the surface, and swamps are found over large tracts extending north beyond the Hot Springs and east to Clear Lake and the region north of Pavant Butte. Sevier Desert thus acts as a huge evaporating pan for disposing of the accumulating water. In the Lake Bonneville stage, when the climate was more humid, the inflow of water was much greater and the rate of evaporation was probably less, with the result that the water accumulated until this entire region was submerged to a depth of several hundred feet.

The fact that this region is the receptacle of surplus surface and ground water and has at the same time an arid climate brings dry and wet areas unexpectedly close together. Thus in the most barren parts of the desert it may be necessary to dig down only a short distance in order to find water, and where the water table comes to the surface the desert gives way to the swamp so suddenly that the traveler may find himself mired where a moment before all seemed dry.

On the Lynn bench the water level is, of course, farther below the surface, but it is probably not beyond the reach of ordinary drilling operations. In the valley at Leamington the ground water stands nearly at a level with the river, and in the well at Lynn it rises approximately to the river level, or within about 100 feet of the upland surface.

## SOIL.

The soil and subsoil on the low flat are impregnated with alkalies left behind by the evaporating waters. The following table presents the results of analyses of samples of soil from two localities where conditions have not been modified by irrigation. The first sample was taken on the flat 5½ miles east of Oasis; the second, near the Desert Wells, 7 miles north of Burtner. On the higher ground of the Lynn bench and the slopes bordering the mountains the ground water is not within the reach of evaporation, and for this reason the soil no doubt contains less alkali.

*Analyses of soil in Sevier Desert.*

[Made by Bureau of Soils, U. S. Department of Agriculture.]

| Location. | Depth within which the soil was taken. | Soluble solids (alkali), per cent of total. | Predominating salts in order named. |
|---|---|---|---|
| | *Feet.* | | |
| No. 1, northeast corner of sec. 3, T. 18 S., R. 6 W., 5½ miles east of Oasis, Utah. | 1 | 0.3 | Bicarbonates and chlorides. |
| | 2 | 3.1 | Sulphates and chlorides. |
| | 3 | 2.6 | Do. |
| | 4 | 2.4 | Do. |
| | 5 | 2.0 | Do. |
| | 6 | 2.6 | Do. |
| No. 2, sec. 1, T. 16 S., R. 7 W., 7 miles north of Burtner, Utah. | 1 | 1.3 | Carbonates and chlorides. |
| | 2 | 1.6 | Sulphates and chlorides. |
| | 3 | 1.7 | Do. |
| | 4 | .8 | Do. |
| | 5 | 1.3 | Do. |
| | 6 | 1.2 | Do. |

## VEGETATION.

The native vegetation is, of course, all of the desert type, but it differs radically in different sections, according to the degree of aridity, the amount of alkali in the soil, and the depth to ground water.

On the Oak City and Fools Creek benches, where the aridity is not extreme and the soil is not overburdened with alkali, tall sagebrush predominates; on the uplands farther west, especially on the Lynn bench, where precipitation is less and conditions are perhaps more adverse in other respects, the sagebrush gives way largely to shad scale; on most of the low flat, where there is little rainfall and much alkali, but where the ground water is near the surface, tall and luxurious greasewood predominates; on some of the low ridges formed by abandoned river channels, where conditions differ somewhat from those on the alkali flat through which these ridges meander, the greasewood is largely displaced by rabbit brush, and an abandoned channel can sometimes be traced long distances by such a band of yellow-topped brush winding through the monotonous expanse of greasewood; in a few areas, generally near springs, patches of grass are maintaining themselves; and in the impassable salt marshes, salt brush holds undisputed possession. The only tracts where conditions seem to be so adverse that no sort of vegetation is able to obtain a foothold are certain low flats which are usually dry, but which at irregular intervals become submerged, with the result that they are alternately extremely dry and extremely wet. The soil samples whose analyses are given were taken in localities where greasewood is dominant.

## IRRIGATION.

The water from Sevier River is used for irrigation at Leamington, Mack, Burtner, Oasis, Deseret, Hinkley, Abraham, and Swan Lake.

These communities have in the past been compelled to contend with two adverse conditions—the breaking of reservoirs and the presence of alkali in the soil. Below Leamington, where the sides and bottom of the river valley consist of unconsolidated material, dams built across the valley have frequently been washed out. The remedy for this difficulty, after much unfortunate experience, is being found in constructing reservoirs farther upstream where rock walls and bottom offer more secure dam sites. The difficulty with alkali has been chronic. With light irrigation the alkali has become concentrated at the surface; with copious irrigation it has been temporarily carried down, but water-logging has resulted. The United States Department of Agriculture has recently made a survey of the region with a view to having established an effective system of underdrainage, by means of which the alkali can be washed away.

### WATER-BEARING BEDS.

That this region has been filled to a depth of many hundreds of feet with stream and lake sediments is demonstrated by the deep railroad wells at Oasis, Neels, and Goss. Some of these sediments have been washed from adjacent mountain sides, but most of them have probably been brought by Sevier River. In as far as they are derived from Sevier River it would be expected that they would be coarse near the point where the river comes out of the mountains and very fine in localities most remote from this point, because an aggrading stream deposits its load of gravel and sand first and holds the fine grains of clay in suspension longest. A gradation of this kind is suggested by Plate III: The section at Lynn is made up largely of gravel and sand; that at Oasis contains numerous beds of sand; at Swan Lake farm and Neels the sections have a smaller proportion of sand, and the sand is mostly of the fine-grained variety reported as quicksand; the section at Goss, still farther from the base of supply, consists for hundreds of feet of almost nothing but clay. Since the water-yielding capacity of a bed decreases with the size of its constituent grains, it might be expected that the prospects of getting wells with good yield would be best near the point where the Sevier comes out of the mountains and poorest in the areas most remote from this point, and the well data given in the ensuing paragraphs indicate that this is the case.

### WELLS ON THE LYNN BENCH AND CANYON MOUNTAIN SLOPE.

The railroad well at Lynn is of special interest because it is the only well on the Lynn bench. It ends in coarse gravel at a depth

of 235 feet and is cased with 12-inch pipe to a depth of 225 feet.[1] When completed, in 1905, it was pumped continuously for 11 hours at the rate of 108 gallons per minute.

*Section of railroad well at Lynn, Utah.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Clay | 8 | 8 |
| Gravel | 10 | 18 |
| Sand | 12 | 30 |
| Sand and gravel | 10 | 40 |
| Sand | 20 | 60 |
| Blue clay | 95 | 155 |
| Blue sandy clay, water-bearing | 60 | 215 |
| Sand | 10 | 225 |
| Coarse gravel, water-bearing | 10 | 235 |

In the valley at Leamington a group of dug wells, about 20 to 25 feet deep, yield plenty of water for domestic use, but have not been given any severe tests. About 1½ miles southeast of Leamington there is a good well 45 feet deep, belonging to Emil Anderson, but farther south on the alluvial slope of the Canyon Range there are no wells. At Fools Creek settlement two holes have been dug, one 145 feet and the other 110 feet deep, and at Oak City a hole was sunk to the depth of 70 feet. In all three of these excavations gravel and coarse sand were passed through but work was stopped before the water level was reached.

There is reason to believe that water-bearing beds of sand and gravel exist in most places below the Lynn bench and the lower part of the slope on which Oak City and Fools Creek are situated.

### WELLS ON THE LOW FLAT.

On the low flat in the vicinity of Deseret, Oasis, Hinkley, Burtner, and Abraham, several hundred successful wells have been sunk. Though water is found within a few feet of the surface, most of the wells are between 100 and 200 feet deep, many are between 200 and 300 feet deep, and a few go to still greater depths. The new railroad well at Oasis was carried to a depth of 710 feet.

The strata penetrated consist essentially of unconsolidated and frequently alternating beds of clay and sand with no bowlders and almost no gravel. The clay preponderates but there are numerous beds of sand of sufficient thickness and coarseness of grain to supply water freely. Several well sections are given to illustrate the character of the strata.

[1] Lee, W. T., Water resources of Beaver Valley, Utah: Water-Supply Paper U. S. Geol. Survey No. 217, 1908, p. 34.

*Section of S. W. Western's flowing well at Deseret, Utah.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Sandy loam (salty water at 12 feet) | 20 | 20 |
| Red gumbo clay | 14 | 34 |
| White chalk | 6 | 40 |
| Gravel | 2 | 42 |
| Red joint clay | 20 | 62 |
| Clay and sand alternating (salty water which did not flow) | 68 | 130 |
| Light blue clay | 30 | 160 |
| Sand (flow of sulphurous water. Some of the oldest wells end in this stratum) | 4 | 164 |
| Dark clay | 3 | 167 |
| Fine yellow sand (flow of soft water, less sulphurous. Many wells end in this stratum). | 43 | 210 |
| Clay and sand alternating, the clay layers about 3 to 4 feet and the sand beds about one-half foot thick (flows of good water from all the sand beds) | 24 | 234 |
| Blue clay | 3 | 237 |
| Dark coarse sand (flow of one-half gallon a minute of soft water, slightly sulphurous; head about 1 foot above the surface) entered | 2 | 239 |

*Section of E. J. Whicker's well near Burtner, Utah (sec. 23, T. 17 S., R. 7 W.).*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Clay with some sand | 19 | 19 |
| Hardpan | 10 | 29 |
| Soft clay with thin layers of sand | 13 | 42 |
| Coarse sand | 15 | 57 |
| Clay and sand in thin layers | 12 | 69 |
| Soft clay | 10 | 79 |
| Light-colored clay | 10 | 89 |
| Clay | 5 | 94 |
| Mud or silt | 6 | 100 |
| Clay | 4 | 104 |
| Sand | 6 | 110 |
| Clay | 5 | 115 |
| Sand | 4 | 119 |
| Clay | 8 | 127 |
| Red sand | 1 | 128 |
| Hardpan | 1 | 129 |
| Soft clay | 8 | 137 |
| Sand | 3 | 140 |
| Gumbo | 6 | 146 |
| Red and blue clay | 8 | 154 |
| Clay with thin bed of sand | 17 | 171 |
| Soft, light-colored clay | 16 | 187 |
| Sand entered. | | |

*Section of deep railroad well at Oasis.*[1]

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Alternating beds of clay and sand, similar to the sections already given | 335 | 335 |
| Sand | 15 | 350 |
| Blue clay | 20 | 370 |
| Red clay | 25 | 395 |
| Sand | 13 | 408 |
| Sandstone | 4 | 412 |
| Blue clay | 68 | 480 |
| Sand | 11 | 491 |
| Red clay | 9 | 500 |
| Blue clay | 27 | 527 |
| Quicksand | 3 | 530 |
| Clay and sand | 29 | 559 |
| Black sand | 3 | 562 |
| Clay and gravel | 13 | 575 |
| Clay | 23 | 598 |
| Cemented gravel | 12 | 610 |
| Soft sandstone | 7 | 617 |
| Clay | 6 | 623 |
| Rock | 2 | 625 |
| Clay | 15 | 640 |
| White clay | 16 | 656 |
| Clay, chiefly yellow | 54 | 710 |

[1] Lee, W. T. Water resources of Beaver Valley, Utah: Water-Supply Paper U. S. Geol. Survey No. 217, 1908, pp. 33-34.

Nearly all of the successful wells are within 10 miles of the margin of the Lynn bench. The farthest north is a group of wells north of Abraham, several recently drilled wells near the north margin of T. 16 S., R. 7 W., and the Desert Wells, near the northeast corner of T. 16 S., R. 7 W. Toward the west wells are found approximately to a line extending from Abraham southward to the river. Toward the south they are found a few miles south of Deseret and Oasis. Toward the east they are found for several miles beyond Burtner and Oasis, and a well was once drilled about 8 miles east of Oasis. Successful wells could probably be obtained farther north and east. In the region south and southwest of the limits outlined, at greater distances from the Lynn bench, considerable drilling has been done, but it was almost invariably unsuccessful. The conditions at Swan Lake, Clear Lake, Neels, and Goss are discussed on pages 97 to 101.

The deep railroad well drilled at Oasis in 1905 is 10 to 12 inches in diameter and 710 feet deep. It passes through a number of water-bearing beds of sand, 10 of which gave rise to flows. At a depth of 335 feet a 15-foot stratum of sand was struck and a flow of about 30 gallons a minute was obtained. In a pumping test the well is reported to have supplied 200 gallons a minute with but slight lowering of the water level. The last part of the drilling was in clay, which yielded no water.

### ARTESIAN CONDITIONS.

In a large proportion of the wells of this region the water rises above the surface. Commonly ground water is reached in these wells at a depth of only a few feet; as work continues, the drill passes through successive beds of water-bearing sand which are separated from each other by layers of clay. The water in these beds is under artesian pressure, and as lower beds are reached the artesian pressure increases slightly until beds may be tapped from which the water rises to the surface or a few feet higher. S. W. Western's well in Deseret is typical. Here the first water was found at 12 feet, and below this level water-bearing beds were passed through at short intervals until the drilling was stopped at the depth of 240 feet. The water did not rise to the surface until a depth of 160 feet was reached, below which every water-bearing bed gave rise to a flow. From no horizon in this well was the water under much pressure nor the yield large. In the deep railroad well at Oasis the most copious flow was obtained after the depth of 335 feet was reached.

Throughout the entire low flat portion of Sevier Desert the head of water coincides so nearly with the surface of the land that a swell or depression almost too gentle to be discerned is sufficient to make

the difference between a flowing and a nonflowing well. Flows are obtained in Oasis and in the region immediately north of that village. Exceptionally strong flows are found east of Oasis for about 3 miles, and the abandoned Phillips well, about 8 miles east, indicated that there may here be a considerable area in which wells would obtain flowing water. Flows are found in most of Deseret, and for about 4 miles up the river to sec. 15, T. 17 S., R. 7 W., also north and west of Deseret to a distance of several miles, and in the region between Deseret and Hinkley. In most of the wells in Hinkley the water does not rise quite to the surface, but at the north end of this village there are several flowing wells. South of Deseret and Oasis flows have been obtained nearly as far as Van, but farther south attempts to get flows have generally been unsuccessful, though there is one isolated flowing well on the Swan Lake farm, nearly 15 miles southwest of Deseret. (See Pl. I.)

Another area in which flows have been obtained is north of the river near the margin of the Lynn bench. (See Pl. I.) It contains the group of flowing wells known as the Desert Wells. This area is limited on the east by the high ground of the Lynn bench and on the south by a tongue of elevated land that extends westward from this bench between the wells and the river. Toward the west and north there is low ground with prospects for flows. However, only 3 miles east of the Desert Wells there is a well, belonging to Bruce Seely, which is 182 feet deep and in which the water stands 12 feet below the surface, and 1¼ miles farther northwest there is a well which is 130 feet deep and in which the water stands 14 feet below the surface.

All of the flowing wells with the possible exception of the one on the Swan Lake farm have a relation to the Lynn bench. This large, level, elevated, and sandy region is the principal catchment area from which the water is supplied to the beds of sand that extend beneath the adjacent low flat. Hence, the artesian pressure is best on that part of the flat that lies nearest this bench, and, in spite of the fact that the surface continues to descend, flows are not generally obtained beyond a certain distance from the foot of the bench. The head of water is about 4,700 feet above sea level at Lynn, 4,625 feet at Burtner, 4,600 feet at Oasis, and less than 4,600 feet farther southwest.

### QUALITY OF WATER.

The water from the railroad well at Lynn contains only moderate amounts of dissolved mineral matter, and most of the ground water below the Lynn bench and the slope of the Canyon Range will probably be found to be fairly good.

*Analysis of water from railroad well at Lynn, Utah.*

[Parts per million.[1] Analyst, Herman Harms.]

| | |
|---|---|
| Total solids | 559 |
| Siliceous matter ($SiO_2$) | 93 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 9 |
| Calcium carbonate ($CaCO_3$) | 136 |
| Calcium sulphate ($CaSO_4$) | Trace. |
| Magnesium carbonate ($MgCO_3$) | 85 |
| Sodium chloride ($NaCl$) | 149 |
| Magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), volatile, organic and loss | 87 |

Throughout the low flat area the shallow ground water is saline, but in most of the localities in which drilling has been done the deeper beds contain water that is relatively soft and not perceptibly saline. Thus in the water from the flowing well of David Day in Oasis the chlorine content is only 37 parts per million; in the water from the Desert wells, 75 parts; in the water from the well of Bruce Seely, 3 miles west of the Desert wells, 63 parts; and in the water from the well of Peter Christensen, northwest of Abraham (SE. ¼ sec. 15, T. 16 S., R. 8 W.), 108 parts. In S. W. Western's well, already referred to as showing typical conditions for the vicinity of Deseret and Oasis, salty water is reported to a depth of 130 feet, but fresh water from all lower beds.

The following is an analysis, made in September, 1910, of the water from the Jensen artesian well, in the northern part of Deseret, Utah. The water is commercially known as the Deseret lithia water. The lithium was not separately determined:

*Analysis of water from Jensen artesian well.*

[Parts per million. Analyst, James R. Bailey.]

| | |
|---|---|
| Total solids | 581 |
| Silica ($SiO_2$) | 48 |
| Iron ($Fe$) | .1 |
| Aluminum ($Al$) | .1 |
| Calcium ($Ca$) | 3.3 |
| Magnesium ($Mg$) | 1.0 |
| Sodium ($Na$) | 209 |
| Potassium ($K$) | 7.8 |
| Carbonate radicle ($CO_3$) | 22 |
| Bicarbonate radicle ($HCO_3$) | 429 |
| Sulphate radicle ($SO_4$) | 28 |
| Chlorine ($Cl$) | 42 |
| Nitrate radicle ($NO_3$) | .6 |

Most of the deep water contains hydrogen sulphide gas, which is given off in small bubbles when the water comes to the surface. The

[1] Originally reported in grains per gallon.

stratum which in Deseret and Oasis usually gives rise to the first flow, and which was struck at the depth of 160 feet in Western's well, seems to be especially strongly charged with this gas.

In the southern part of Sevier Desert saline water has generally been found at all depths penetrated by the drill. The flowing well of P. N. Peterson, 1 mile northeast of Van, is 258 feet deep and yields water that contains about 675 parts per million of chlorine. On the farm of J. V. Conk, 4 miles southwest of Deseret, three wells have been drilled, the deepest going to the depth of 227 feet, but the water found was all salty. Deep wells have been drilled at Swan Lake, Clear Lake, Neels, and Goss in the hope of finding good water, but none of these wells has been successful.

The following analysis of water from the railroad well at Oasis is not typical of the best deep water of the region. There is some reason for believing that water from shallow sources enters this well.

*Analysis of water from railroad well at Oasis.*

[Parts per million.[1] Analyst, Herman Harms.]

| | |
|---|---|
| Total solids | 1,325 |
| Siliceous matter ($SiO_2$) | 45 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 3 |
| Calcium carbonate ($CaCO_3$) | 54 |
| Calcium sulphate ($CaSO_4$) | 45 |
| Magnesium carbonate ($MgCO_3$) | 75 |
| Sodium chloride ($NaCl$) | 864 |
| Magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), volatile, organic, and loss | 239 |

## WAH WAH VALLEY.

### GENERAL FEATURES.

Wah Wah Valley, which on the old maps is called Preuss Valley, is bordered on the east by the San Francisco Mountains and on the west by the Wah Wah Range and the southern extension of the Confusion Mountains. It lies chiefly in Beaver County, but its lower part extends into Millard County and leads to Sevier Lake. (See Pl. I.) It is a wide, open valley with large alluvial slopes and so few topographic irregularities that from a single vantage point the eye can sweep a large part of its area. In the Bonneville stage the waters of the ancient lake extended far up this valley and formed a distinct strand on its sides; in the Provo stage the lake occupied only the lower part. (See fig. 2.) The axis of the valley descends several hundred feet from its upper end to Sevier Lake, but in one locality between Newhouse and Sevier Lake there is an obstruction back of which a playa has formed. Wah Wah Valley can consist-

[1] Originally reported in grains per gallon.

ently be considered to end with this playa, but it is convenient here to discuss the entire area to the south end of Sevier Lake. West of the lower part of this structural trough and tributary to it lies an extensive and rugged upland area which contains several soil-covered valleys of considerable size.

### SOIL.

Samples of soil were taken at the point where the road from Black Rock to Ibex crosses the axis of the valley, and these samples were analyzed by the United States Bureau of Soils, with the results shown in the following table. This crossing is below the Provo shore line and below the playa, but well above Sevier Lake and at a point where the valley has considerable gradient, as is shown by the presence of a dry channel.

*Analysis of soil south of Lake Sevier.*

| Depth within which the soil was taken. | Soluble substances (alkali). Per cent of total. | Predominating salts in order named. |
|---|---|---|
| *Feet.* | | |
| 1 | 0.5 | Chlorides and carbonates. |
| 2 | .9 | Sulphates and chlorides. |
| 3 | 1.0 | Do. |
| 4 | 1.2 | Do. |
| 5 | .9 | Do. |
| 6 | 1.3 | Chlorides and sulphates. |

### RAINFALL.

No rainfall observations are recorded by the United States Weather Bureau for Wah Wah Valley, but aridity is plainly shown by the vegetation and surface features. At Black Rock and Frisco the average annual precipitation is between 8 and 9 inches, and at Garrison it is still less. This amount of rainfall has thus far not proved sufficient for dry farming. The data for Frisco are given in the following table:

*Precipitation (in inches) at Frisco.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1897 | ...... | 0.30 | 0.44 | Tr. | 0.20 | 0.11 | 0.16 | 0.19 | 1.21 | 1.50 | 0.45 | 1.00 | ...... |
| 1898 | 0.42 | .10 | .12 | 0.41 | 2.59 | .11 | .97 | 1.46 | .00 | .31 | .15 | .24 | 6.88 |
| 1899 | .10 | .65 | 2.56 | 1.01 | .08 | .36 | .81 | .18 | Tr. | .51 | .28 | Tr. | 6.54 |
| 1900 | .11 | .04 | .03 | 1.73 | ...... | .04 | Tr. | .05 | 1.41 | .77 | .55 | .05 | ...... |
| 1901 | .35 | 2.36 | .28 | .86 | 1.42 | .97 | 1.76 | .64 | Tr. | .68 | Tr. | .75 | 10.07 |
| 1902 | .95 | .02 | .72 | .10 | Tr. | Tr. | .74 | .82 | .47 | .15 | 1.22 | .39 | 5.58 |
| 1903 | .75 | 1.66 | .68 | 1.49 | 1.88 | .66 | .72 | 1.12 | .82 | .85 | .02 | .07 | 10.72 |
| 1904 | .50 | .64 | .97 | .10 | 2.49 | .11 | .86 | .83 | .45 | .41 | .00 | .22 | 7.58 |
| 1905 | .66 | 1.44 | 1.71 | .58 | 1.44 | .02 | .58 | 1.04 | 2.32 | .89 | .83 | .30 | 11.81 |
| 1906 | .10 | .56 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | .98 | .95 | ...... |
| 1907 | 1.12 | .42 | .60 | .00 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1908 | ...... | ...... | 1.30 | .30 | 1.58 | .49 | .42 | 1.00 | 1.87 | 1.57 | .00 | .60 | ...... |
| Average | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 8.45 |

### WATER SUPPLIES.

Wah Wah Valley is entirely destitute of an irrigation supply and contains very few watering places for man or beast. Wah Wah Spring—the only spring of consequence in the region—is situated in Beaver County, on the west side of the valley, and its water is led by gravity through a pipe line to Newhouse, a mining town on the east side. At Kelley's, a short distance north of Wah Wah Spring, a small supply has been developed from surficial sources.

### GROUND-WATER PROSPECTS.

Conditions are not favorable for finding ground water in this region. Beneath the broad slopes that flank the valley water is almost certainly at a great depth, and may be entirely absent. Even along the axis of the valley the gradient is in most places so steep and the altitude so much higher than that of Sevier Lake that it is not likely that water would be found near the surface. At the playa the drainage is evidently checked, but there may be no underground structure competent to impound the water that percolates beneath the surface. A drill hole was at one time put down in the valley west of Newhouse with the hope of obtaining a supply for that town. Detailed information could not be obtained, but it is known that the project proved unsuccessful.

In the elevated valleys to the west the rock waste is as a rule not deep, and the underlying formations consist chiefly of limestones and quartzites which are likely to allow the ground water to escape. Small supplies may exist in basins lined with igneous rock, but the chances of finding any such supplies are poor.

## SEVIER LAKE BOTTOMS.

### FLUCTUATIONS OF THE LAKE LEVEL.

The Pleistocene Lake Bonneville is now represented only by a few small isolated sheets of water and swampy areas that occupy the lowest depressions of the ancient lake bottom. Sevier Lake is the largest of these residual water bodies in the area covered by this report. It receives supplies from Sevier River and loses them by evaporation. As the amount of evaporation depends on the water area, the size of the lake is an expression of equilibrium between inflow and evaporation, between gain and loss.

Mr. Gilbert, in his monograph on Lake Bonneville, states that Sevier Lake was first explored and accurately mapped in 1872 by R. L. Hoxie and Louis Nell, of the Wheeler Survey, and that at that time it was about 28 miles long; its water surface was 188 square

miles in extent; its maximum depth was about 15 feet, and its outline that indicated in Plate I. He also states that in January, 1880, the lake was virtually dry and its bed was crossed on foot where the water had been deepest.

A large part of the water that would normally flow into the lake is now diverted for irrigation and that which still reaches the lake represents an economic loss that should, as far as possible, be stopped. To save all of the water of Sevier River in years of heavy rainfall would, however, require a very much greater storage capacity than is required in years of light or even average precipitation. In 1880 and in several preceding years the water of the river was so nearly monopolized by irrigators that the lake dried up, but since that time, in spite of probable increased use for irrigation, a surplus has again accumulated. The outline of the lake shown in Plate I is copied from a map of Utah compiled by Gilbert Thompson in 1899.[1] In the autumns of 1908 and 1909 a lake existed which was somewhat larger than that indicated in Plate I, but whose margin was separated from the shore line of 1872 by a flat miry belt. The outline of the north end of the lake in 1908 is shown on the topographic map of the Fish Springs quadrangle. (See Pl. IV.)

### POSITION OF THE LAKE.

Sevier Lake occupies the lowest depression in the Sevier drainage basin, but this depression is not in the interior of the desert plain, remote from mountain masses, but in a relatively narrow trough between the House and Cricket ranges. The reason for this position is evident. Originally the lowest depression may have been farther from the elevated areas, but the basin was filled to great depths with sediments brought chiefly by Sevier River, and the quantity of material deposited varied inversely with the distance from the point where the river made its exit from the mountains. This was true both when the river discharged into Lake Bonneville and when it was an aggrading stream building an alluvial fan. Hence the locality most remote from the river's exit received the least sediment, was built up the most slowly, and eventually remained at the lowest level. This most remote locality is the present site of Sevier Lake.

### QUALITY OF THE LAKE WATER.

The water of the lake is too saline to be used as a supply for live stock. In 1872, in connection with the Wheeler Survey, a sample was taken at a point on the west shore remote from the inflow, and this sample was analyzed by Dr. O. Loew, with the results shown in

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[1] Gannett, Henry, A gazetteer of Utah; Bull U. S. Geol. Survey No. 166, 1900, Pl. I.

the following table.[1] During the periods that the lake was dry some of the deposited salt was probably covered with mud or dust which later prevented it from being redissolved. On the other hand, the quantity of water is at present less than in 1872, and this fact tends to make the concentration greater.

*Analysis of water in Sevier Lake.*[a]

| | Parts per million. | Percentage composition of the anhydrous residue. |
|---|---|---|
| Total solids | 86,400 | ........ |
| Calcium (Ca) | 120 | 0.14 |
| Magnesium (Mg) | 2,100 | 2.43 |
| Sodium and potassium (Na+K) | 28,900 | 33.45 |
| Sulphate radicle ($SO_4$) | 17,580 | 20.35 |
| Chlorine (Cl) | 37,700 | 43.63 |
| | | 100.00 |

[a] Recalculated from hypothetical compounds in grains per gallon.

### GROUND-WATER PROSPECTS.

The sediments brought to Sevier Lake were not only meager in quantity but fine grained in character, and hence they are unpromising as a source of water supply. The conditions are similar to those on the opposite side of the Cricket Mountains, where unsuccessful railroad wells were drilled. Nevertheless some coarse material was washed down from the adjacent ranges and this material may contain supplies of fresh water. Gravelly water-bearing lenses are most likely to be found at the base of alluvial fans heading in the largest canyons, out of which have come the most gravel and the most water.

## WHITE VALLEY.

### GENERAL FEATURES.

White Valley occupies a closed basin more than 60 miles long and about 900 square miles in area. It is bordered on the west by the Confusion Range, which separates it from Snake Valley, and on the east by the House Range, which separates it from Sevier Desert. (See Pl. IV.)

The central flat of the valley is about 4,400 feet above sea level. The loftiest part of the inclosing mountain rim is formed by the House Range, whose two highest peaks are Antelope Mountain and Granite Peak, respectively 9,586 feet and 9,725 feet above sea level, or about one mile above the valley flat. The lowest notch in the rim is at Sand Pass, between the House and Fish Spring ranges, where the altitude is between 4,700 and 4,800 feet.

[1] Geog. and Geol. Surveys W. 100th Mer., vol. 3, 1875, p. 114.

The strata of the bordering mountains consist chiefly of Paleozoic limestones and quartzites. In the House Range they dip toward the east, away from the valley, and their outcropping edges form a steep, rugged westward-facing wall which for many miles towers precipitously above the valley flat. In the northern part of the Confusion Range the dip is also toward the east, which here is toward the valley, and the slope from the mountains to the central flat is relatively wide and gentle, like the east slope of the House Range. Hence the valley is asymmetrical, the lowest part lying near the base of the more lofty range. (See Pl. IV.)

The lowest part of the valley constitutes a nearly flat area, many miles long and several miles in average width. In some parts a miniature eolian topography is imposed upon this flat surface, a fantastic landscape being produced by the presence of innumerable hummocks, the tallest of which are 12 to 15 feet high. These hummocks consist chiefly of residual clay held in place by clumps of salt bush or other vegetation, while the surrounding surface has been lowered by wind erosion. In other parts of the flat, probably the lowest tracts where flood waters occasionally collect, the surface is smooth and quite destitute of vegetation of any sort. Toward the south the valley becomes more constricted and trough-like, but the central axis remains low and, with some interruptions, retains its playa character. At the tapering south end it is hemmed in by rock walls.

When Lake Bonneville existed, White Valley contained a large bay, which, during both the Bonneville and Provo stages, was connected with the main body of the lake by narrow straits at the north end. After the water was lowered a short distance beneath the Provo level, the straits were drained and the bay was converted into a lake that had no outlet.

White Valley is uninhabited. Although there are no records of precipitation in the valley, the sparseness of the desert vegetation and the scarcity of water plainly indicate aridity. Almost the only use made of the region is for sheep grazing, the flocks being brought in during the winter when the light snowfall helps to solve the problem of water supply. Ibex, a winter supply station for sheep herders, is situated a few miles west of the southern extremity of the valley. At this point an attempt at dry farming, thus far unsuccessful, is being made.

### SPRINGS.

The White Valley drainage basin has no permanent streams and only a few small springs. Two seepage springs are reported near the base of the Confusion Range. One of these, known as Skunk Spring, is said to be about 5 miles east and 1 mile south of the sum-

mit of Cowboy Pass; the other, known as Gregory Spring, about 8 miles farther south. Though they are small and little known, they are valuable watering places for stock on the range.

Antelope Spring is situated in the House Range, about 1 mile east of the divide and one-half mile north of the road leading from Snake Valley to Oasis. (See Pl. IV.) It yields several gallons per minute of good water and is a valuable watering place for travelers.

A group of small springs, including Coyote, Willow, Tule, and South Tule Springs, occur in the low part of the valley. (See Pl. IV.) They are all on the central flat, west of the axis of the valley and near the base of the long slope from the Confusion Range. Coyote Spring consists of a circular depression in which tules are growing. This depression contains water which is evidently supplied from underground sources but which was not overflowing at the time the spring was seen. The water, though perceptibly mineralized, is used for drinking and for watering live stock. The other springs of the group are said to be similar to Coyote Spring. Like Antelope Spring, these springs are used as watering places by persons traveling between Snake Valley and the settlements in Sevier Desert.

At Ibex there is no spring, but storm water collected from a steep mountain side is stored in reservoirs formed out of natural cavities in the rock.

### GROUND-WATER PROSPECTS.

There are no wells in this valley, but it is not improbable that in certain localities ground water could be found. The topographic map (Pl. IV) shows that the central flat is about 4,400 feet above sea level, which is not only far below the surrounding uplands but also slightly below the level of Sevier Lake, 200 feet below the level of the flowing district surrounding Deseret, 300 to 500 feet below the water level in Snake Valley, and only slightly above the surface of Fish Springs Flat and the south end of Great Salt Lake Desert. Obviously the ground water of this valley does not escape to the surrounding valleys, and it is therefore probable that it has accumulated in the sediments below the central flat, a condition also indicated by the group of springs on this flat.

Beneath the flat the sediments may be too fine to yield water freely or too heavily charged with alkali to furnish water of good quality. The chances of obtaining satisfactory supplies are better near the foot of the slopes, where the elevation is not much greater than on the flat but where the sedments are likely to be coarser and less strongly impregnated with alkali. Localities near the mouths of the largest canyons are the most promising. The central part of the tapering southern appendage of the valley has a low altitude nearly to the south end, and may have ground water at moderate depths.

Most of the extensive west slope and the steep east slope of the valley lie so high above the flat that their ground water is no doubt either far below the surface or entirely drained away. In the elevated tributary valleys near the south end the prospects of finding ground water, except at great depths, are also poor, especially where limestones and quartzites are present and igneous rocks are absent.

## FISH SPRINGS VALLEY.

### GENERAL FEATURES.

Fish Springs Valley is bounded on the east by the Thomas Range and on the west by the Fish Springs Range. Both of these ranges consist of westward-dipping limestones and quartzites with associated masses of volcanic rock, the latter being especially abundant in the Thomas Range. On the east side of the valley the rocks dip toward the center of the valley and the slope is correspondingly wide and gentle. This slope is continuous with the high tract that shuts in the valley on the south, and slope and high tract together form a large upland area. On the west side of the valley the strata have apparently been faulted up and their outcropping edges form a precipitous mountain wall at the base of which is a steep and narrow alluvial slope that diminishes in size toward the north until it almost disappears. At the foot of the slopes from the east, south, and west is a broad swampy alkali flat that merges on the north with the desolate expanse of Great Salt Lake Desert. The only permanent inhabitant in this drainage basin of nearly 400 square miles, is to be found at Thomas's ranch, near the northwestern extremity of the valley, but the Fish Springs and Drum mining camps are located on the mountain rim, just beyond the divides. (See Pl. IV.)

### SPRINGS.

No permanent streams rise in the mountains, and the only mountain spring worthy of mention is Wildhorse Spring in the main Thomas Range, 4 miles south and 11 miles east of Thomas's ranch. However, in the central flat, near the base of the Fish Springs Range, there is a group of springs some of which are large.

The Hot Springs, which are located on the flat a short distance from the north end of the Fish Springs Range and less than 1 mile south of the Tooele County line, include a group of tuffaceous mounds with vents from which water is flowing, or has flowed in the past. Hydrostatic equilibrium exists between the water in the different springs, and hence the springs that have the highest mounds have

only a small yield or are extinct, while the most copious flow observed comes from a vent around which almost no mound has yet been built, and which therefore discharges at a lower level. The spring that supplies the bathhouse issues from a mound about 25 feet in diameter and yields several gallons per minute. The water has a temperature of 104° F., is highly mineralized, and deposits incrustations of salt. The water from the large spring has a much higher temperature. A variety of colors, including red, brown, bright green, olive green, and black, are displayed in the vicinity. They are due to chemical precipitates and to filamentary algæ that thrive in the hot water. The large mounds that yield little or no water are distinguished by their bright red color, which is probably due to more complete oxidation of the precipitates at these places than in the vicinity of more active springs.

Between the Hot Springs and the mountain there are two small springs that yield water of lower temperature, and about 1 mile southeast of the Hot Springs is the Big Spring. The latter is located on the flat within a few yards of the foot of the mountain, the alluvial slope here being virtually absent. It consists of a deep pool which has vertical or overhanging walls, and is filled with clear water that issues at the rate of several hundred gallons per minute. Other springs are located at Thomas's ranch and between the ranch and Big Spring, and a number of large springs issue along a line extending to a little over a mile south of the ranch. Most of these springs, like the Big Spring, consist of deep, steep-sided pools filled with clear water, which is supplied from underground sources and which rises by artesian pressure and overflows at a nearly constant rate. The pools are inhabited by small fish for which the springs are named.

Although these springs are known as "cold springs," in distinction from the Hot Springs, they are thermal in the sense that the temperature of their water is higher than the normal temperature of the shallow ground water of the region. The water in the spring at the ranch has a temperature of 78° F., which is nearly 30 degrees above normal. This water is not excessively mineralized and is freely used for drinking.

About 7 miles south of Thomas's ranch is Cane Spring, which consists of a number of seeps at the base of the alluvial slope. The water is highly mineralized but is used for live stock and forms one of the supplies for the freighters operating between the Utah mine and Oasis.

The Devils Hole, which is near Cane Spring but a little farther up the slope, is a deep circular hole filled with water within 10 or 15 feet of the top. Beneath the water surface, which is about 15 feet in diameter, the walls are overhanging, as in some of the pools

of the Fish Springs. This hole has been described by G. K. Gilbert,[1] who states that "it appears to be due to the undermining action of subterranean currents flowing in channels sufficiently open to permit the removal of even coarse detritus, and the salinity of the water suggests that these channels may have been opened by the solution of deposits of salt."

The Fish Springs Range has evidently been produced by faulting, the break in the strata occurring along the east side. Moreover, very recent faulting is shown by a small fresh scarp which runs parallel to the east margin of the range and in which the alluvial and lacustrine sediments have been displaced.[2] The linear arrangement of the Fish Springs along the east side of the range, together with their high temperature and copious yield, suggests that their origin may be associated with the fault.

### WATER IN UTAH MINE.

The Utah mine, which is near the north end of the Fish Springs Range, was sunk through limestone near a contact of intrusive rock. It appears that the first water was found between the depths of 800 and 820 feet, which is somewhat lower than the level of the springs in the valley. The water comes in small quantities from crevices in the rock. It contains a large amount of common salt, but it is the only supply at the mine and is used for drinking and other purposes.

*Analysis of water from Utah mine.*[3]

[Parts per million; analyst, C. C. Crismon; date, September, 1901.]

| | |
|---|---|
| Total solids | 2,255 |
| Volatile and organic matter | 239 |
| Silica ($SiO_2$) | 18 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 13 |
| Calcium (Ca) | 64 |
| Magnesium (Mg) | 67 |
| Sodium and potassium (Na+K) | 591 |
| Sulphate radicle ($SO_4$) | 164 |
| Chlorine (Cl) | 1,096 |

### GROUND-WATER PROSPECTS.

In general the best chances of obtaining satisfactory wells are at the base of the slopes, near the margin of the central flat (Pl. IV). Beneath the flat itself the ground water is probably near the surface but it is likely to be poor in quality and, if fine-grained lake

[1] United States Geog. and Geol. Surveys W. 100th Mer., vol. 3, 1875, p. 110.
[2] Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, p. 353.
[3] Recalculated from hypothetical combinations in grains per gallon.

sediments prevail, its yield is likely to be small. Farther up the slopes the water probably stands at great depths or has been drained away entirely. Small supplies, similar to those developed at Joy, may exist near the surface in certain localities in the hills and mountains to the east and south where igneous rocks occur.

## SNAKE VALLEY.

### GENERAL FEATURES.

Snake Valley is a structural trough that trends in a direction somewhat east of north. (See Pls. I and IV.) From its head, in Nevada, it extends diagonally across the State line, passes through the western parts of Millard and Juab counties, and opens upon Great Salt Lake Desert. On the east it is bordered by the low, barren ridges of the Confusion Range; on the west, by the lofty Deep Creek Range, in western Juab County, and by high mountains farther southwest in Nevada. The length of this trough from the vicinity of Burbank to where it merges into Great Salt Lake Desert, near the Tooele County line, is about 80 miles, and its total drainage area within the State of Utah is approximately 2,000 square miles. Its axis descends toward the north but not with equal gradient in all parts. (See Pl. IV.) The valley may be considered to consist of three sections: The upper section includes the part south of Garrison and is sometimes called "Lake Valley," the middle section stretches from Garrison to Trout Creek and forms Snake Valley proper; the lower section extends north from Trout Creek. The middle and lower sections are shown in Plate IV.

In the highest stage of Lake Bonneville the lower and middle sections of Snake Valley contained a large bay (fig. 2) and the upper section was traversed by a tributary river described as follows by Mr. Gilbert:[1]

> A large channel whose habit indicates a stream comparable with the smaller rivers of the basin, enters Snake Valley from the south at a point just east of Wheeler Peak, known as the Snake Valley settlement [Garrison]. The channel ends at the margin of the old lake, and appears to have contained a stream tributary to the lake, which disappeared at the same time. It is now occupied near the settlement by a streamlet from the adjacent mountain known as Lake Creek, but this enters the channel at its side, and played no important part in its formation. Above its confluence the channel has essentially the same dimensions, and these continue as far as it was traced, about 20 miles from its mouth.

In the Provo stage the middle section was virtually drained and the bay extended only a short distance south of Trout Creek.

Conspicuous shore features were constructed by the waves in Snake Valley Bay. Especially characteristic are large terraces bordered on the outside by heavy embankments resembling railroad grades and

[1] Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890, pp. 184, 185.

forming "natural reservoirs." So perfect and regular are these embankments that they are believed by some of the inhabitants of the region to represent the labors of an ancient people.

## RAINFALL AND VEGETATION.

The rainfall records of the United States Weather Bureau, given in the following table, although not very comprehensive, plainly indicate an arid climate, the precipitation in some years being less than 5 inches. These records are corroborated by the character of the native vegetation. The broad, gravelly slopes that flank the valley on both sides contain only a meager cover of dry, stunted bushes. In the axial portion of the valley, where ground water is near the surface, rabbit brush, greasewood, and salt brush are found, the dominating type among these three in any locality depending largely on the amount of alkali in the soil. The Confusion Range, like the Basin ranges that lie farther east, is notably barren; but the Deep Creek Range, which is several thousand feet higher, supports large trees and evidently receives more moisture than either the valley or the Confusion Range.

*Precipitation (in inches) in Snake Valley.*

**Garrison.**

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1903 | 0.66 | 0.60 | 0.20 | 0.38 | 1.16 | 0.54 | 0.05 | 0.55 | 0.38 | 0.23 | Tr. | Tr. | 4.75 |
| 1904 | .07 | 1.49 | .62 | .06 | .97 | .41 | .93 | .95 | .55 | .94 | 0.00 | 0.22 | 7.21 |
| 1905 | .37 | 1.30 | .30 | .99 | 1.83 | Tr. | .10 | .83 | .85 | .00 | 2.14 | .11 | 8.82 |
| 1906 | ...... | Tr. | 2.47 | 1.58 | .77 | .06 | .33 | ...... | .50 | .10 | 1.98 | .58 | ...... |
| 1907 | .64 | .55 | .90 | Tr. | .42 | .20 | .21 | .05 | .05 | .64 | .49 | .20 | 4.35 |
| 1908 | .25 | .89 | .16 | .10 | .47 | .10 | .65 | .56 | ...... | 1.41 | .33 | .26 | ...... |
| Average | .40 | .81 | .77 | .52 | .94 | .22 | .38 | .59 | .47 | .55 | .83 | .23 | 6.28 |

**Trout Creek.**

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1905 | ...... | 1.45 | 0.95 | 0.25 | 0.60 | 0.00 | 0.00 | 0.75 | 1.67 | 0.00 | 1.25 | 0.23 | ...... |
| 1906 | 0.14 | .43 | .92 | 1.18 | 1.92 | 1.70 | .28 | 1.00 | 1.22 | 1.20 | 2.20 | .15 | 12.34 |
| 1907 | 1.85 | .51 | 1.05 | .00 | .79 | .69 | Tr. | 1.56 | .37 | .52 | Tr. | .95 | 8.28 |
| 1908 | .50 | 1.40 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |

**Callao.**

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1902 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0.44 | 0.28 | ...... |
| 1903 | 0.50 | ...... | ...... | Tr. | 2.56 | ...... | 0.05 | Tr. | 0.31 | 0.18 | .16 | .07 | ...... |
| 1904 | 1.50 | 0.83 | 1.16 | 0.28 | .77 | 1.52 | Tr. | 0.54 | .36 | .76 | .00 | .05 | 7.77 |
| 1905 | .05 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |

*Precipitation (in inches) in Snake Valley*—Continued.

**Fish Springs (Utah Mine).**

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1899 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 2.40 | 0.37 | 0.73 | ...... |
| 1900 | 0.05 | 0.80 | 0.05 | 4.65 | 0.20 | 0.07 | 0.70 | Tr. | 1.37 | .42 | ...... | ...... | ...... |
| 1901 | 22 | ...... | ...... | ...... | ...... | .24 | .25 | Tr. | .00 | ...... | ...... | ...... | ...... |

## SPRINGS AND STREAMS.

Some parts of Snake Valley have flowing water during most of the year, but other parts of the axial region are normally dry or are occupied by alkali flats or salt marshes. If the climate were humid, or perhaps if it were only somewhat less arid, a permanent stream would flow through the entire length of the valley. The barren Confusion Range has no streams and is almost destitute of springs, but the loftier and better-watered mountains west of the valley give rise to a number of small irrigation streams. In the succeeding paragraphs the different streams and springs are described in the order in which they are found in passing northward through the valley.

*Big Spring and Lake Creek.*—Big Spring is situated in Nevada, about 10 miles up the valley from Burbank. The water issues in large volume from gravel not far from a limestone cliff that borders the valley on the west. This water appears to be of good quality. Its temperature was found to be 63.5° F. The spring gives rise to Lake Creek, which flows northeastward to the Burbank settlement and into the reservoir shown in Plate I. For some miles below the Big Spring smaller springs well out of the gravel and help to augment the size of the creek. The flow of the creek below these springs is reported to be 18 second-feet. The water is used for irrigation on six ranches at Burbank, above the reservoir, and on five ranches at Garrison, below the reservoir, but its duty is apparently low. A mile or more south of the reservoir a large spring, known as Burbank Spring, issues from the gravelly bench on the east side of the valley and supplies water of good quality, the temperature of which is 57° F. Another spring exists in the same vicinity, but nearer the creek.

*Snake Creek.*—A small stream, known as Snake Creek (Pl. I), rises in the mountains west of Garrison and furnishes the irrigation supply for two ranches at this settlement. Its flow is largely provided by the melting of snow at high altitudes.

*Baker Creek.*—About 7 miles north of Garrison, Baker Creek enters the valley from the west. (See Pl. I.) Its surplus waters join those from Snake and Lake creeks and flow northward along the axis of the valley toward Conger's ranch, producing a swampy tract. There are also springs in the vicinity of Conger's ranch, and small springs, known as Cane Springs, occur several miles west.

*Knoll Springs.*—The Knoll Springs comprise several groups of springs which are arranged along a north-south line. They are on the east side of the valley, but on low ground. (See Pl. IV.) The southernmost group is near the road leading from Meecham's ranch to Cowboy Pass, about 7 miles east-northeast of the ranch. Some of these springs consist of pools with overhanging walls, but more characteristic are those that consist of mounds, or knolls, near the top of which the water issues. The largest of these knolls are over 100 feet in diameter and more than 10 feet high. Apparently the knolls have been built over pools by the growth of vegetation and the accumulation of dust, as is explained on pages 44 and 45.

The shelves of the pool springs tremble when they are stepped upon, and horses or cattle that venture too far out on them are likely to break through and become mired, but the knolls are so firmly built that they can be traversed with impunity by man and beast. As far as was observed, none of the springs has a large flow, but those which have no knolls or only small ones, and which therefore issue near the level of the normal land surface, yield more than those which discharge at a higher level near the tops of well-developed knolls.

The water does not seem to be highly mineralized. From some of the springs bubbles of hydrogen sulphide were seen to escape, probably resulting from the decomposition of the vegetable matter with which the springs are surrounded. The temperature of the water in one spring was found to be 70.5° F.

*Kell Springs, etc.*—About halfway between Smithville and Butson's ranch, along the road to Garrison, are four springs known as the Kell Springs (Pl. IV). They are on the west side of the valley but not greatly above the central flat. The most northerly of the group consists of a swampy seepage area, about 30 feet in diameter, covered with water cress. Water that is cool and good to the taste flows from the spring, but is soon lost by seepage and evaporation. A short distance southeast of this spring there is a mound, approximately 75 feet long, 30 feet wide, and 5 feet high, from an orifice at the top of which a small quantity of water issues. A few rods farther south is a small pool of clear water overgrown with cress, the flow from which amounts to several gallons per minute. The water is good to the taste and has a temperature of 58° F. A few rods still farther south there is a mound, more than 100 feet long and perhaps 5 feet high, from three points near the margin of which water flows at the rate of several gallons per minute.

At Butson's ranch a small spring of good cold water issues from a gravelly bank on the valley slope and a small amount of water comes from a canyon to the west. Other streams in the vicinity are Henry Creek, used for irrigation on Meecham's and Simonson's ranches, and Smith Creek, used on George Bishop's ranch at Smithville.

*Warm Springs.*—A mile or more west of Gandy post office, which is situated high up on the alluvial slope on the west side of the valley, there is a small mountain that consists of distorted and steeply dipping limestone strata. The Warm Springs issue from crevices in the rock at the base of the precipitous south slope of this mountain, and give rise to a stream (Pl. I) that is estimated to be larger than Lake Creek, and whose flow is said to be independent of seasonal changes. The temperature of the water coming from the largest vents is 81.5° F. Calcareous precipitates are found in large quantities at the springs, and they form thick incrustations on the sides and bottom of the stream channel. Deposits of this kind in the vicinity of the springs show that water once issued at points that are now dry. Algæ and water cress abound in the stream. The water appears to be only moderately mineralized and is used for domestic purposes and for irrigation on the ranch of James Robison, on the fields of a small Indian settlement near by, and on a ranch farther down the valley. The total acreage irrigated is not large, and the water is evidently not doing full duty.

*Springs at Foote's ranch.*—A large group of pool and knoll springs is situated on low ground on the east side of the valley, between 1 and 2 miles south and southeast of Foote's ranch, which is in sec. 9, T. 16 S., R. 18 W. (See Pl. IV.) Most of the pools are surrounded and partly inclosed by marginal shelves, and their clear waters are inhabited by small fish. The largest knolls are about 10 feet high. The flow of these springs is not noticeably affected by seasonal changes, and their total yield amounts to a number of second-feet. The water appears to be of good quality, and its temperature, in five springs that were tested, ranges between 66.5° and 68° F. The spring having the largest yield consists of a pool which is about 125 feet in diameter and is said to be 40 feet deep.

*Springs bordering the Salt Marsh.*—Numerous springs are found on the west side of the Salt Marsh, which lies north of Foote's ranch. Some of these springs consist of small pools, but in others the water seeps or wells up directly from the porous ground. None are large, but together they yield much water. The temperature of the water in the so-called Cold Spring is 55° F., and in the spring at C. A. Conklin's (the old Gandy ranch) it is 58° F. Neither of these is of the pool type.

The flow of these springs is said to be least in the summer and greatest in the fall. In the fall and winter the Salt Marsh fills with water, which disappears in the summer, but this may be due more largely to a difference in the rate of evaporaton than to differences in the yield of the springs.

*Springs between Salt Marsh and Trout Creek.*—North of the Salt Marsh the axial part of the valley contains a number of pool springs

which discharge into swampy tracts. The largest spring of this group that was observed is at Miller's ranch, about 8 miles south of Trout Creek. It consists of an oval pool about 125 feet long and 75 feet wide, around which a dam several feet high has been built. The discharge from this pool is several hundred gallons per minute. The water does not appear to be highly mineralized. Its temperature at the outlet was found to be 64° F.

*Springs at Trout Creek.*—In the lowest part of the valley, at Trout Creek post office, there is an area of seeps and small springs some of which are of the pool type. The temperature of the water in one spring was found to be 55° F.

*Springs and streams in Pleasant Valley.*—Pleasant Valley heads in Nevada and leads southeastward to Snake Valley, which it enters between Trout Creek and Gandy. (See Pl. I.) A small stream which issues from Water Canyon, to the north, furnishes the irrigation supply at Henroid's ranch, and other canyons furnish still smaller supplies. Along the axis of the valley there are numerous springs some of which yield copiously.

*Streams from the Deep Creek Range.*—Deep Creek Range is exceptional among the basin ranges of the region in that it gives rise to a number of permanent streams (Pl. IV). Some of these are on the west side and are tributary to Deep Creek, which flows northward into Tooele County; others drain the east slope and provide small quantities of irrigation water for the lower section of Snake Valley. The waters of Birch Creek and Trout Creek are led to the Trout Creek settlement where they furnish the irrigation supply for two ranches, and the waters of Indian Farm Creek, Thoms Creek, and Basin Creek are led to Callao where they supply three ranches.

*Willow Springs and similar springs farther north.*—At Callao, near the Tooele County line, there is a swampy area that contains a labyrinth of pool springs of various sizes, together known as the Willow Springs. Some of the pools barely overflow but others give rise to vigorous streams. They contain fish and abound in water cress. Redding Spring, another large spring of the pool type, is situated 6 miles farther north.

*Character of the springs.*—From the foregoing account it is evident that this valley, from Big Spring, 10 miles south of Burbank, to Redding Spring, 6 miles north of Callao, is characterized by an abundance of large springs, most of which, together with the Fish Springs and Hot Springs, exhibit certain traits in common.

Not only are many of the springs large, a number yielding over one second-foot and a few yielding several times this amount, but, according to local reports, the flow of the large springs is not affected by seasonal changes.

The pools and knolls are distinctive of the group, though they do not include the Big Spring nor the Warm Springs, which are the largest springs in the valley. The pools and knolls are found only on low ground, not much above the bottom of the valley, but the Warm Spring is at a much higher level. Characteristic of the pools are their depth, their overhanging shelves, the fish they contain, and the abundance of water cress and other vegetation that they support.

Characteristic also of many of the pools, and of the Big Spring and Warm Springs as well, is the high temperature of their water. The mean annual temperature of this region is about 50° F., in contrast with which the following maximum temperatures were observed in springs:

*Temperature (°F.) of spring water in Snake and Fish Springs valleys.*

| | |
|---|---|
| Hot Springs | Near boiling. |
| Warm Springs | 81.5 |
| Fish Springs (small spring at Thomas's ranch) | 78.0 |
| Knoll Springs | 70.5 |
| Springs at Foote's ranch | 68.0 |
| Spring at Miller's ranch | 64.0 |
| Big Spring | 63.5 |

Considerable difference in temperature usually exists among the different springs of the same group, the warmest water being where the flow is most copious. This relation was found, for example, in the Hot Springs, Warm Springs, and springs at Foote's ranch. The temperature of the water in large pools with little discharge is no doubt affected by atmospheric conditions.

The origin of these springs is discussed on pages 43–45.

### WELLS AND GROUND-WATER PROSPECTS.

*Burbank.*—In the valley of Lake Creek, above the reservoir, the ground-water level is near the surface, and shallow dug, drilled, or driven wells yield copious supplies of good water. On the farm of B. P. Hockman, 2 miles north and one-half mile east of Burbank post office, two wells have been drilled on ground only a few feet above the creek level, one to a depth of 18 feet and the other to a depth of 40 feet. In sinking these wells alternate beds of clay, sand, and gravel were passed through. The first water was struck at the depth of 9 feet and at 18 feet a good supply that rose by artesian pressure within 4 feet of the surface was obtained.

Considerable quantities of ground water no doubt exist in this part of the valley and could be made available for irrigation by a small lift, but it is improbable that good artesian wells could be obtained. In the lower part of White Sage Valley (also known as Antelope Valley), pump wells can probably be obtained at moderate depths,

but in the middle and upper parts of this valley the ground water is likely to be far below the surface or to be drained away entirely.

*Garrison.*—In the vicinity of Garrison the depth to water decreases toward the north. In this part of the valley a number of wells have been sunk, most of which have fallen into disuse. Abandoned wells are reported as follows: SE. ¼ SW. ¼ sec. 6, T. 22 S., R. 19 W., a dug well 40 feet deep; SW. ¼ SE. ¼ sec. 31, T. 21 S., R. 19 W., a dug well 35 feet deep; SE. ¼ SE. ¼ sec. 31, T. 21 S., R. 19 W., a dug well 30 feet deep; NW. ¼ SW. ¼ sec. 32, T. 21 S., R. 19 W., a dug well 15 feet deep. A well at the hotel, sunk almost entirely through gravel, receives a small supply of water from seepage near the bottom. At the south end of the settlement (SE. ¼ NW. ¼ sec. 7, T. 22 S., R. 19 W.), two unsuccessful attempts were made to obtain flows. One hole is reported to have been sunk to a depth of nearly 200 feet, at which level bedrock was struck.

*Between Garrison and Conger's ranch.*—The old Conger ranch is situated in a low, swampy area that receives the drainage from the creeks farther up the valley. At this point a well was drilled which is said to have reached a depth of more than 100 feet and to have found a supply of good water that rose within 3 feet of the surface.

In the low tract traversed by Baker Creek ground water could probably be found in some abundance, and it is possible that in the lowest parts flows would be struck. The large branch valley on the east side of Snake Valley, and heading in the direction of Ibex, receives less water than Baker Creek Valley, but up to some distance beyond the 5,000-foot contour, as shown in Plate IV, there is a reasonable chance of obtaining wells at moderate depths and with supplies sufficiently large for stock purposes.

*Between Conger's ranch and Trout Creek.*—In the entire stretch between Conger's ranch and Trout Creek the ground is saturated with water virtually to the level of the surface along the axis of the valley, and wells can probably be obtained on the central flat and near the foot of the alluvial slopes, especially on the west side.

A number of shallow wells sunk on the west side of the valley yield water of satisfactory quality and in sufficient amount for domestic and stock purposes. On the ranch of William Meecham (sec. 21, T. 18 S., R. 19 W.), situated about 90 feet above the center of the valley, there is a dug well 28 feet deep which yields water that is somewhat hard, but otherwise good. Two similar wells, one 12 feet and the other 18 feet deep, are situated at a little lower level on this ranch, and a well of the same type supplies Simonson's ranch in the same locality.

On the ranch of George Bishop (NW. ¼ sec. 3, T. 17 S., R. 19 W.), there are two dug wells, one 35 feet and the other about 45 feet deep. The water level here fluctuates considerably, and the wells, at first

more shallow, have been deepened several times to procure a permanent supply. The water is hard but otherwise good and is used for drinking and for culinary purposes.

At the old Barry ranch, near the banks of the Salt Marsh, there is an abandoned dug well in which the water stood 14 feet below the surface.

The two ranches at Trout Creek, situated near the central axis of the valley, obtain their culinary supply from wells 15 feet deep in which the water level fluctuates with the season. The water in these wells is considered of good quality though harder than the stream water. On Alfred Bishop's ranch a 2-inch well was at one time sunk to a depth of over 200 feet in quest of flowing water, but the project was not successful.

*Pleasant Valley.*—Several wells sunk in Pleasant Valley obtain satisfactory culinary supplies, but attempts to get flows in this valley have thus far been unsuccessful.

*Trout Creek to Callao.*—Trout Creek is situated in a constricted part of Snake Valley, south of which the valley trough is relatively flat and swampy, but north of which it descends at a rate of about 25 feet per mile until it begins to merge with the desert flat. North of Trout Creek the benches on either side of the valley are high and wide and the valley proper is relatively low. These high benches, especially the one on the west side, receive large contributions of water which is transmitted to lower levels, and there is therefore reason to expect that in the lower parts of the valley good supplies can be obtained at moderate depths. Probably, however, the axial gradient is too great to allow the ground water to accumulate under sufficient head to give rise to flows.

The only well reported in this region is a 50-foot dug well on the claim of Harry Parker, near the center of the valley, not far from the line between secs. 34 and 35, T. 12 S., R. 17 W. Most of the material excavated in sinking this well was compact clay, but near the bottom, quicksand, sand, and water-bearing gravel were found. The yield is reported to be ample and the quality satisfactory, but the water is under little or no artesian pressure.

*Callao.*—In the northern part of Juab County, Snake Valley expands into Great Salt Lake Desert and a large alluvial slope extends from the Deep Creek Range to the desert flat. In the vicinity of Callao, where the slope from the mountains gives way to the dead level of the desert, and where the Willow Springs, already described, are located, a number of flowing and nonflowing wells have been sunk. Ground water is here reached within a few feet of the surface, as, for example, in the dug well of E. W. Tripp, which is only 12 feet deep and is filled with water to within 3 feet of the surface.

The flowing wells are 1½ to 2 inches in diameter and range from about 40 to 175 feet in depth. Their section consists of clay, sand, and gravel, the largest flows thus far obtained coming from coarse gravel at depths of 90 to 100 feet. In most wells the water rises only a few feet above the surface, but original heads of 15 feet and more are reported. Toward the west the flowing area is sharply limited by the rise in the surface of the land. Flows are obtained on F. G. Kearney's and R. E. Bagley's ranches, but farther west the water remains below the surface. Toward the east, in the direction of the desert, the limits of the flowing area are less definitely known, but satisfactory flows have been obtained as far as 2 miles east of the Kearney ranch buildings. (See Pl. I.)

One of the best wells of this group is near the house of F. J. Kearney, in the SE. ¼ sec. 1, T. 11 S., R. 17 W. It is 2 inches in diameter and 93 feet deep and ends in coarse gravel, from which the water will rise to a level 6 feet above the surface, while at a level 1 foot above the surface the flow is about 20 gallons per minute.

The water from the flowing wells is, as a rule, of better quality than the shallow ground water. The following table contains an analysis, made at the laboratories of the Utah agricultural experiment station, of water from one of the flowing wells at the residence of F. J. Kearney. This sample, which is believed to be typical of the well waters of the Callao Basin, contains only moderate amounts of the mineral constituents generally found in ground waters.

*Analysis of water from flowing well of F. J. Kearney, Callao, Utah.*

[Parts per million. Analyst, J. E. Greaves.]

| | |
|---|---|
| Total solids | 249 |
| Silica ($SiO_2$) | 16 |
| Iron (Fe) | Trace |
| Calcium (Ca) | 38 |
| Carbonates, stated as calcium carbonate ($CaCO_3$) | 228 |
| Sulphate radicle ($SO_4$) | 4 |
| Chlorides, stated as sodium chloride (NaCl) | 126 |

*Between Callao and Fish Springs.*—The northern part of Juab County between Callao and the Fish Springs Range, into which Great Salt Lake Desert extends, lies so low and is so nearly level (Pl. IV) that the ground-water table nearly coincides with the surface. Desert and swamp are here intimately associated, and the same tract is frequently converted from one to the other. Yet the prospects for obtaining satisfactory wells are not good. The region formed a part of the bed of ancient Lake Bonneville, and the sediments beneath it are likely to be too fine to yield water freely and too heavily impregnated with salt to furnish water of good quality.

The unfavorable conditions found in parts of Sevier Desert are likely to be found here also. In general the prospects both as to quantity and quality become poorer as the distance from the Deep Creek Range increases.

Many years ago two 2-inch holes were sunk on the flat near the west base of the Fish Springs Range, the location being approximately sec. 13, T. 11 S., R. 15 W. According to current report, they reached a depth of about 300 feet, where drilling was stopped by hard rock. The water that was found was salty and remained about 10 feet below the surface. One of the wells was finished, however, and for a number of years its water was used at the mine for live stock, laundry, and toilet, and, to some extent, for drinking purposes.

Another hole was drilled on the flat near the old stage station known as Boyd, in or near sec. 21, T. 11 S., R. 15 W. This project was also unsuccessful but definite information as to the difficulties could not be obtained.

## IRRIGATION.

The amount of land irrigated in Snake Valley is small as compared with the amount of water furnished by streams and springs. This is due in part to the fact that some of the largest supplies can not be led by gravity upon land adapted for agriculture, but also in part to the fact that available supplies are not used to their full capacity. Much water could be saved if adequate storage facilities could be provided. Some of the "natural reservoirs" formed by the waves of Lake Bonneville are in positions where they could be brought into service at relatively small cost, but it has not been demonstrated that they could be rendered sufficiently waterproof to make their use feasible. Some water could probably also be saved by practicing winter irrigation.

The water from many of the large springs in the low parts of the valley serves no useful function except to produce the growth of a small amount of poor grass. The chief obstacle to the use of these springs for irrigation lies in the poor drainage and alkali character of the soil upon which the water can be led. Whether it could be made profitable to pump this water to higher and better land is doubtful.

Practically the only irrigation now accomplished with water from wells is at Callao, where a few small tracts are watered from flowing wells. In certain parts of the valley, already indicated, considerable quantities of water could be recovered from underground sources, but pumping would generally be required to make these supplies available on good soil. At Callao the quantity recovered by natural flow could be increased if a series of wells of large diameter were sunk.

## PAROWAN VALLEY.

### PHYSIOGRAPHY AND GEOLOGY.

Parowan Valley lies at the northeast base of a high plateau from which it is separated by a fault scarp several thousand feet high—the northward continuation of the Hurricane Ledge. On the face of this escarpment and in the canyons that have been cut into the plateau since its differential elevation are exposed the edges of several rock series that have a great total thickness, display a variety of rich colors, and cover a wide range of geologic time. The highest sedimentary strata—bright-hued Tertiary deposits—are covered in some places with somber-colored volcanic rocks.

Parowan Valley is separated from Rush Lake Valley by a mountainous region that is several miles wide and consists of sedimentary strata and associated dark volcanic rocks. This mountainous region is traversed by several faults and the strata dip in different directions. Farther southwest the valley is separated from Rush Lake Valley by only a low pass which projects from the high plateau to the mountainous west wall. On the north the valley is shut in by a mountainous area in which volcanic rocks are abundant. The lowest notch in the rim of the basin is formed by Hieroglyph Canyon, which has been cut boldly through the west wall. (See Pl. II.)

According to the best available data, the Parowan drainage basin comprises between 550 and 600 square miles, nearly two-thirds of which belongs to the plateau. Since the Tertiary deformation, which apparently brought the basin into existence, the plateau has been greatly eroded and the resulting sediments have in large part been deposited in the valley. Since only small amounts of rock waste were brought into the valley from the west, the alluvial slope on the east side comprises most of the valley, and Little Salt Lake, which occupies the lowest depression, hugs the west border. Near the plateau the slope is steep, but near Little Salt Lake it passes into a flat plain with only slight gradient.

Not all of the material eroded from the plateau has remained in the valley, for the drainage of the basin once had an outlet through Hieroglyph Canyon, and the outflowing stream carried some rock waste with it. The valley lies above the level of the highest stage of Lake Bonneville, but there can be little doubt that when the ancient lake existed the climate was sufficiently humid to cause a stream to flow out through the canyon. Possibly the canyon was formed at this time, but more probably it is the work of a stream which was in existence before the west wall of the valley was raised and which maintained its course by cutting down its channel as rapidly as the region was lifted. That the canyon has long ago fallen into disuse is shown

by the talus and alluvium that has accumulated in it and also by the salt that has accumulated in the lowest depression of the valley. An indistinct strand, perhaps 20 feet above the present level of Little Salt Lake, shows that this lake has at one time had larger dimensions than it has at present.

### RAINFALL.

The records of the United States Weather Bureau, given in the following table, show that during a period of 18 years, from 1891 to 1908, inclusive, the annual precipitation at Parowan ranged between 7.04 and 20.87 inches, and averaged 12.54 inches. Large sagebrush is prevalent on the alluvial slopes of this valley. Dry farming has not been extensively undertaken, but much interest is at present manifested in this mode of agriculture and it will probably be given a thorough trial in the near future. That the plateau receives more precipitation than the valley is shown by the trees and other vegetation which it supports.

*Precipitation (in inches) at Parowan.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1890 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0.93 | 0.59 | 0.43 | 0.34 | ...... |
| 1891 | 1.46 | 2.07 | 2.57 | 1.57 | 1.14 | 0.20 | 1.24 | 0.76 | 2.10 | .00 | .00 | 1.13 | 14.24 |
| 1892 | .47 | 1.03 | 1.79 | 2.03 | .83 | .04 | .66 | 1.24 | .00 | 2.32 | .20 | .39 | 11.00 |
| 1893 | .84 | 1.03 | 1.23 | 1.42 | 1.34 | .00 | 2.08 | 1.65 | 1.11 | Tr. | 1.38 | .72 | 12.80 |
| 1894 | 1.65 | .85 | 2.65 | 1.27 | .55 | .57 | .78 | 1.40 | .72 | .65 | Tr. | 1.88 | 12.97 |
| 1895 | 1.94 | 2.82 | 1.93 | .47 | .87 | .06 | .70 | .23 | .29 | .58 | 1.28 | .90 | 12.07 |
| 1896 | .16 | .48 | .71 | .83 | .93 | .08 | 1.69 | 3.00 | .47 | .36 | .30 | .16 | 9.17 |
| 1897 | 1.50 | 3.45 | 3.76 | .95 | .51 | .02 | .79 | 1.56 | 1.84 | 2.48 | .73 | .88 | 18.47 |
| 1898 | 1.99 | 1.20 | 1.66 | .64 | 3.35 | .24 | 1.19 | 1.46 | .25 | .30 | .72 | .82 | 13.82 |
| 1899 | .12 | 1.10 | 2.18 | 1.20 | 1.19 | .82 | .72 | .82 | .08 | .78 | .31 | 1.60 | 10.92 |
| 1900 | .51 | .23 | .18 | 2.64 | .61 | .13 | .11 | .84 | .82 | .56 | .34 | .07 | 7.04 |
| 1901 | .63 | 1.84 | .85 | 1.61 | .88 | .50 | .04 | 3.35 | .04 | .32 | .03 | 96 | 11.05 |
| 1902 | 1.18 | .31 | 1.83 | .21 | .18 | .06 | .49 | .76 | .50 | .61 | 1.86 | 1.03 | 9.02 |
| 1903 | 1.10 | .77 | 1.94 | 1.66 | 1.10 | .49 | .41 | 1.46 | 1.00 | 2.03 | Tr. | .53 | 11.89 |
| 1904 | .43 | 1.46 | 2.11 | 1.27 | 2.07 | .07 | .98 | 1.23 | .17 | .74 | Tr. | .79 | 11.32 |
| 1905 | .52 | 1.54 | 2.29 | .66 | 1.99 | Tr. | .75 | .37 | 3.80 | .12 | 1.11 | .32 | 13.47 |
| 1906 | 1.40 | .93 | 3.99 | 1.95 | .62 | Tr. | 1.71 | 3.10 | 3.49 | .41 | 2.09 | 1.18 | 20.87 |
| 1907 | 1.15 | 1.58 | 1.61 | 1.23 | 2.85 | .31 | .34 | .65 | .33 | 2.16 | .32 | 1.20 | 13.73 |
| 1908 | .86 | 1.19 | .62 | .39 | 1.16 | .16 | 2.16 | .49 | 1.64 | 1.61 | .50 | 1.02 | 11.80 |
| Average | 1.00 | 1.33 | 1.88 | 1.22 | 1.23 | .21 | .94 | 1.28 | 1.03 | .88 | .61 | .84 | 12.54 |

### STREAMS AND MOUNTAIN SPRINGS.

*Parowan Creek.*—The largest stream in the basin is Parowan Creek, which supplies the village of Parowan with water for irrigation. Like other streams of its type, its flow is very irregular, generally being largest in May and June when the bulk of the snow in the mountains melts. Much of the flood water and winter discharge are lost. In October, 1908, the flow was estimated to be 15 second-feet. The total area irrigated with this supply is reported to be about 2,000 acres.

*Red and Little creeks.*—Red Creek and Little Creek furnish the irrigation supply for the Paragonah settlement. The water in Red Canyon comes largely from springs and its volume varies less than

that of streams which depend chiefly on the melting of snow. In October, 1908, the discharge from Red Canyon was about one-half as great as from Parowan Canyon. The Red Canyon water is reported to irrigate about 800 to 1,000 acres, and the water from Little Creek, a short distance north, about 300 acres.

*Streams and springs north of Little Creek.*—The only streams of any consequence north of Little Creek are Willow Creek and Cottonwood Creek, which together are said to furnish enough water to irrigate about 100 acres. Buckskin Valley, high up in the mountains, has three good springs which supply a large number of cattle. There is also a spring in Fremont Pass and several others near the north end of the basin.

*Streams and springs south of Parowan Creek.*—The largest supply south of Parowan Creek comes from Summit Creek and is used for irrigation at the village of Summit. There is also a small supply at the Winn Ranch, a short distance west of Summit, and there are numerous springs along the margin of the mountain between Parowan and Summit, some of which are used to irrigate small tracts.

### VALLEY SPRINGS.

Many springs occur in the valley along a line extending southeastward from Buckhorn Spring, where the steep part of the alluvial slope gives way to the nearly level plain that occupies the lowest part of the valley. Many of the springs consist of small pools, in which respect they resemble somewhat the Fish Springs and the springs in Snake Valley. They furnish good supplies for live stock and culinary purposes but do not yield enough to be of much value for irrigation. Many small springs, some of which yield salty water, occur on both sides of Little Salt Lake.

### FLOWING WELLS.

Flowing wells have been obtained throughout an area that is about 16 miles long and extends from a point 1 mile northeast of Buckhorn Spring to a point several miles west of Parowan, as is shown in Plate II. Most of the best flows are found along the spring line or a short distance east of it, but flows have also been obtained at various points on the flat between the spring line and the salt lake. Several score of flowing wells are at present in use and new wells are being sunk.

The flowing water is derived from deposits of sand and gravel interbedded with layers of clay, and the artesian conditions do not depend on the structure of the rocks. It is not obtained from a single bed nor from several definitely recognized beds, but from all porous materials below a certain level. In many wells the first flow

is struck at a depth of about 70 feet, but as the drill penetrates deeper it is likely to discover stronger flows from beds of gravel that are more freely porous and that contain water under slightly better head. The deepest flowing well reported is about 400 feet deep, and many of the largest yields are derived from wells between 200 and 300 feet deep, but most of the wells are less than 200 feet deep. The water from these wells has not been analyzed but is apparently of good quality.

The wells thus far drilled are all small, most of them being 2 inches, and a few 3 inches, in diameter. They are finished with heavy iron casing, and water is usually admitted into them at only one level. Many of the wells flow less than 10 gallons per minute, but a few of the 3-inch wells yield from 25 to nearly 100 gallons per minute. In none of the wells is the water under much pressure.

The largest flowing well supplies have been developed on the farm of J. L. Lowder (secs. 25, 26, and 35, T. 33 S., R. 9 W.), where 14 wells furnish water for irrigating about 100 acres; on the farm of Frank Culver (NE. ¼ sec. 9, T. 34 S., R. 9 W.), where about a dozen wells together yield more than one-half second-foot; and on the farm of James C. Robison, 2 miles south of Buckhorn Spring, where a number of flowing wells furnish water for irrigation. On several other farms irrigation supplies are obtained from flowing wells.

The wells of Frank Culver, all of which are within several rods of each other, discharge into a small reservoir, from which the water is led to irrigated fields. The following table gives the principal facts in regard to this group of wells.

*Wells of Frank Culver, Parowan Valley, Utah.*

| No. | Diameter. | Depth. | Temperture of water. | Natural flow. |
|---|---|---|---|---|
| | *Inches.* | *Feet.* | ° *F.* | *Gallons per minute.* |
| 1 | 2 | .......... | 49.8 | 11 |
| 2 | 2 | .......... | 49.8 | 5 |
| 3 | 2 | .......... | 50.3 | 5 |
| 4 | 2 | 180(?) | 52.3 | 4 |
| 5 | 3 | 233 | 52.4 | 37 |
| 6 | 2 | 50 | 50.0 | 13 |
| 7 | 2 | 160(?) | 50.0 | 11 |
| 8 | 2 | .......... | 51.5 | 5 |
| 9 | 3 | 140 | 51.0 | 40 |
| 10 | 2 | 50 | 51.0 | 23 |
| 11 | 3 | 202 | 53.0 | 50 |
| 12 | 3 | 242 | 53.3 | 43 |
| Total.. | .......... | .......... | .......... | 247 |

The inhabitants of this valley have only recently come to realize that supplies of substantial value can be developed by drilling wells, and further development is being prosecuted with enthusiasm. The conditions warrant sinking test wells to greater depths than have

thus far been reached. The faulted structure of the basin makes it probable that the unconsolidated sediments are very thick, and the deeply buried sediments are likely to contain beds of gravel with water under good head. Drilling should not, however, be carried into bed rock. The California method of drilling wells, described on pages 60–64, could be introduced to good advantage in this valley.

As the supply of underground water is a definitely limited quantity, none of it should be wasted. Unless it is found practicable to build reservoirs of sufficient size to store the water which the flowing wells would yield during the winter, these wells should be closed at the end of the irrigation season. If the number of wells is greatly increased they will interfere with each other. Eventually it may be found profitable to install pumping plants rather than to depend entirely on artesian pressure, because more water could be recovered by pumping, and it could be applied to more productive soil. On the higher levels of the alluvial slopes there are no prospects of securing flows, and the success thus far attained should not lead to costly drilling experiments on high ground or in rock formations.

### WATER BENEATH THE BENCH LANDS.

A number of nonflowing wells have been sunk on the lower part of the alluvial slope directly west of Parowan and in other localities. These wells yield good water which remains at a depth proportionate to the elevation of the surface above the flowing area. Good pump wells can generally be obtained by sinking to moderate depths on the lower and middle parts of the alluvial slopes.

### CULINARY SUPPLIES.

In the three principal settlements of this valley the supplies for drinking and culinary use are taken from the streams which furnish the irrigation supplies or from ditches leading from these streams. Water from springs in the canyons or on the mountain sides, if led to the settlements through pipe lines, could be protected from pollution, and would therefore be safer for drinking and culinary purposes than the stream water.

## RUSH LAKE VALLEY.

### PHYSIOGRAPHY AND GEOLOGY.

A great fault with a throw of several thousand feet extends northeastward through Iron County, passing Kanarraville, Cedar City, Summit, Parowan, and Paragonah. East of the fault the rock formations have been thrust relatively upward, producing a high plateau with a steep escarpment known as the Hurricane Ledge. Since the displacement the edge of the plateau has been carved by

stream erosion into a mountainous area. This escarpment forms the east border of Rush Lake Valley as far north as the vicinity of Enoch, where it swings eastward and forms the border of Parowan Valley, while a low range that trends more nearly northward forms the divide between Rush Lake and Parowan valleys.

West of the southern part of Rush Lake Valley are the Iron Mountains, but these mountains disappear toward the north, leaving only a low divide between the northern part of this valley and the Escalante Desert. There are two other low points in the rim of Rush Lake Valley. One is at the Iron Springs, where there is an outlet for the drainage of a part of the valley; the other is in the vicinity of Kanarraville, where an inconspicuous divide is all that separates Rush Lake Valley from the drainage basin of Colorado River. (See Pl. II.)

The rocks exposed in this region have a great total thickness and include Carboniferous, Jurassic, Triassic, Cretaceous, and Tertiary strata. The youngest formations are exposed in the northern part of the plateau area of this county and older beds come to light farther south. The Jurassic, Triassic, and Tertiary formations have conspicuous colors, but the intervening Cretaceous beds have a somber gray aspect. Volcanic rocks of Tertiary age are found on the plateau, in the Iron Mountains, in the range between Rush Lake and Parowan valleys, and in the area southwest of Cedar City.

Rush Lake Valley exhibits the characteristic features of a closed basin in an arid region. Its peripheral parts consist of broad, open, alluvial slopes, and its central part consists of a nearly level plain, the lowest depressions of which are occupied by lakes, swamps, and dry alkali flats. The alluvial slopes and central plain are underlain by sediments which were washed out from the mountains and which consist of alternating beds of gravel, sand, and clay.

A low divide, extending from the mouth of Coal Creek Canyon to Iron Springs, separates the valley into two basins. The south basin drains into a small salt lake known as Shirts Lake. (See Pl. II and fig. 13.) The north basin is drained in part into Rush Lake, but the water from Coal Creek may come to rest in depressions farther south or may find its way into Escalante Desert through the valley at Iron Springs.

### RAINFALL.

The rainfall observations at Cedar City cover only a few years, but they indicate that the precipitation at this point does not differ greatly from that at Parowan, where the record extends over a much longer period. That the climatic conditions in Rush Lake Valley are similar to those in Parowan Valley is also indicated by the general aspect of the vegetation. Dry farming has been attempted on a small scale and some success has been attained.

*Precipitation (in inches) at Cedar City.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1899 | ...... | ...... | ...... | ...... | ...... | ...... | .47 | 1.00 | Tr. | 1.03 | .39 | 1.18 | ...... |
| 1900 | .81 | .29 | .22 | 3.65 | .34 | .11 | .46 | .61 | 1.18 | .39 | .38 | ...... | ...... |
| 1905 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 3.36 | .54 | ...... |
| 1906 | .68 | 1.28 | 3.78 | 1.77 | .72 | ...... | ...... | ...... | 1.56 | .10 | 2.07 | 1.31 | ...... |
| 1907 | .93 | 1.31 | 1.58 | .88 | 2.63 | .34 | 1.16 | 2.43 | .53 | 3.24 | .20 | .93 | 16.16 |
| 1908 | .55 | 1.44 | .77 | .38 | 1.16 | .15 | 2.45 | 1.23 | 2.30 | 2.31 | .32 | .67 | 13.73 |

## STREAMS.

Coal Creek, the largest stream that discharges into Rush Lake Valley, collects its waters in the plateau area and debouches from its canyon at Cedar City. Here it furnishes enough water to irrigate about 3,000 acres, of which 1,700 acres come under the primary water right. Owing to lack of storage facilities, a large part of the winter flow and of the flood waters resulting from heavy storms, runs to waste.

Shirts Creek rises on the plateau in an area south of Coal Creek drainage basin, and its water is used by the small settlement at Hamiltons Fort, where between 200 and 300 acres are under cultivation. The flow of this stream fluctuates widely, being generally greatest in the spring when the snow melts. An attempt was made to store the flood waters, such as are at present lost, by utilizing as a reservoir the basin formed by the volcanic rocks that occur some distance west of the mountain border, but these rocks are so badly fissured that they allowed the water to escape.

Kanarra Creek provides the irrigation supply for the settlement at Kanarraville. Like Shirts Creek it rises on the plateau, receives much of its water directly from the melting of the snow, and hence fluctuates greatly in size. Some water has been stored in a reservoir south of the village. The total area brought under irrigation is reported to be somewhat less than 300 acres.

Several very small streams are found in the Iron Mountains, among which are Queatchupah Creek, whose supply is used to irrigate about 50 acres at McConnell's ranch (fig. 13), and the streamlet in Leach Canyon, which is utilized at the Duncan ranch.

## SPRINGS.

Ward's ranch is in the NE. ¼ sec. 12, T. 34 S., R. 11 W., about 5 miles north of Enoch, and near the base of a cliff of volcanic rock that belongs to the mountainous area between Rush Lake and Parowan valleys. At this ranch there is a group of springs which yield approximately one second-foot of water. The water issues on low ground, where it gives rise to a swampy tract, but, as far as possible,

it is used for irrigating grass land. The origin of these large springs seems to be associated with the volcanic rock.

Volcanic rock similar to that found at Ward's ranch forms a low ridge east of Enoch and separates the relatively high bench land in the vicinity of Summit from the lower level of Rush Lake Valley. Near the west base of this ridge, along a line extending northward from Enoch for more than a mile, there are numerous springs, some of which are large. Considerable water also issues from springs in a small canyon cut through the ridge. The water is derived, at least in part, from saturated sediments east of the ridge, the fissures in the volcanic rock probably having a function in conducting it. The water is of good quality and is used for irrigation, although some of it issues at too low a level to be applied advantageously.

A number of small springs are found on the low ground that surrounds Shirts Lake. Among them are Eight-mile Spring, situated a short distance northwest of the lake on the NW. $\frac{1}{4}$ sec. 16, T. 36 S., R. 12 W., and Mud Springs, situated a short distance south of the lake on about the NW. $\frac{1}{4}$ sec. 9, T. 37 S., R. 12 W. (fig. 13). There are also seepage springs in the valley west of Kanarraville.

Iron Springs are located in the valley that leads from Rush Lake Valley, through the northern part of the Iron Mountains, into Escalante Desert. The water issues at different points along a stream channel which passes through this valley. In part the springs seem to result from the overflow of the ground water that saturates the sediments of Rush Lake Valley, much as some of the Enoch Springs result from the overflow of the ground water in Parowan Valley. Accordingly their yield varies with the season, being greatest in the spring, when some of the surface waters of Rush Lake Valley are discharged through this outlet, and least in the fall and the winter, when the water supply is meager. At the time the area was visited, October, 1908, nearly a second-foot of water issued from the springs and flowed through the stream channel. This water is used to only a small extent for irrigation but forms a valuable supply for live stock. The Church ranch, near the springs, is important as the halfway house between Cedar City and the railway station at Lund.

### FLOWING WELLS.

*Webster's well.*—The well of Francis Webster is situated on low ground a few miles southwest of Enoch, in the NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 14, T. 35 S., R. 11 W. (Pl. II). It is 2 inches in diameter and 153 feet deep. The water is rather hard, but apparently otherwise of good quality and has a temperature of about 54° F. When the well was completed the water remained at a depth of 7 feet, and for seven years it had to be pumped in order to bring it to the surface, but in July,

1907, it began to overflow, and from that time until October, 1908, when the investigation was made, it overflowed continuously. At the latter date the natural yield was about 3½ gallons per minute. This interesting rise in the head of the water is probably to be correlated with increase in rainfall. The records for Parowan show that in 1900, the year in which the well was drilled, the precipitation was lighter than in any other year within the period of 18 years during which records have been kept at that station, and that in each year from 1899 to 1904, inclusive, the precipitation was below the average. These records show further that in 1906 the precipitation was heavier than in any other year within the 18-year period, and that in 1907 it was again above the average. The records at Cedar City also show unusually light precipitation in 1900 and unusually heavy precipitation in 1907.

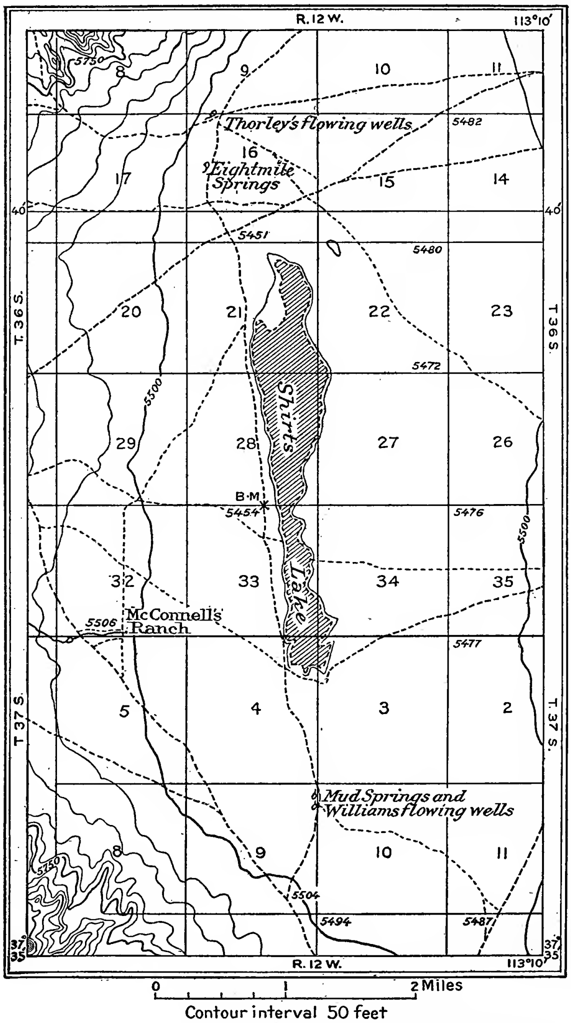



FIGURE 13.—Map of a part of the south basin of Rush Lake Valley.

*McConnell's well.*—A small flow is reported from a well that belongs to Mr. McConnell and is situated in Cedar Bottoms several miles west of Webster's well.

*Thorley's wells.*—About half a mile north of the Eightmile Springs, near the northwest corner of sec. 16, T. 36 S., R. 12 W. (fig. 13), are four flowing wells which belong to A. Thorley. They are small

in diameter and are said to be only 80 or 90 feet deep. The water is apparently good but the natural flow is very slight.

*Williams's wells.*—Five flowing wells have been drilled by George Williams in the vicinity of Mud Springs, south-southeast of Shirts Lake. (See fig. 13.) The first was drilled in about 1892 and is two inches in diameter and 85 feet deep. In this well the first water was struck 8 feet below the surface, and the casing extends only to this depth. According to report, the flow was about 20 gallons per minute when the well was completed, but it is now much less, probably owing to deterioration of the well.

The other four wells, which are located nearly a mile farther west, are 2 inches in diameter and about 90 feet deep. One is cased to a depth of 80 feet, the others only to 8 feet, where the first water was struck. Each of these wells is said to have flowed about 5 gallons a minute when they were completed, but they have since been neglected and their yield has diminished. They are situated on somewhat lower ground than the Thorley wells, which fact may account for their larger original flow. The water is good to the taste and was found to have a temperature of 54.5° F.

In this locality Mr. Williams has drilled to the depth of 240 feet, the drill apparently passing through unconsolidated sediments only. He states that in drilling to this depth five or six beds were struck that gave rise to flows, some of them stronger than the 90-foot flow, and that all the water is of good quality.

*Wells at Kanarraville.*—On low ground less than 1 mile west of Kanarraville there is a well, belonging to William Ford, which is reported to be considerably less than 100 feet deep. In the past this well yielded a small amount of water by natural flow but at the time it was visited no water flowed from it.

In the village of Kanarraville, at a somewhat higher altitude than Ford's well, a 2-inch hole was drilled to a depth of 240 feet. Mr. Williams, the driller, reports that several water-bearing strata were found and that water from the depth of 190 feet rose within 1 foot of the surface. The drill was finally lost and the well was abandoned.

### NONFLOWING WELLS.

*In northern part of valley.*—At Ward's ranch (NE. ¼ sec. 12, T. 34 S., R. 11 W.) a well 2 inches in diameter was drilled to a depth of 250 feet, the last 13 feet of which are said to be in volcanic rock. The water comes from the bottom and rises within 8 feet of the top of the well, or nearly to the level of the flat area west of the well. The water is of good quality and is used for drinking and other purposes. Less than a mile north of this ranch another 250-foot well is reported, the water here rising within 4 feet of the surface. Other

wells have been sunk in the bottoms farther west, in all of which the water stands within a few feet of the surface.

Several shallow wells have been dug in the vicinity of Enoch. The well of Hiram Jones, which is located on the narrow bench between the ridge and the bottom lands, is 20 feet deep and is filled with water within 6 or 8 feet of the top; the well of J. H. Armstrong, situated on lower ground near the foot of the bench, is only 12 feet deep; the well of William Grimshaw, southwest of Enoch, on the W. ½ of SW. ¼ sec. 12, T. 33 S., R. 11 W., is 17 feet deep and contains 3 feet of water; the well of John Webster, about 1 mile south of Enoch, is 30 feet deep; the well of David Bullock, on the W. ½ sec. 24, T. 35 S., R. 11 W., was 48 feet deep and contained 10 feet of water until recently when the sides caved in and the well fell into disuse. Wells of the same type, many of them abandoned or in bad repair, are found at different points on Cedar Bottoms. Most of the wells that have been mentioned yield good water, but in some of the wells on the bottoms the water is salty.

*In southern part of valley.*—At Hamiltons Fort a depth of 100 feet has been reached without striking ground water, but about 1½ miles west of this settlement there are pump wells 30 to 40 feet deep and shallow wells are also found between Hamiltons Fort and Kanarraville. There is a dug well only 12 feet deep at Bower's (NW. ¼ sec. 3, T. 36 S., R. 12 W.), where the altitude is about the same as at Thorley's flowing wells, and there was formerly a good well with the same depth at the Church ranch (N. ½ sec. 20, T. 35 S., R. 12 W.).

## IRRIGATION WITH GROUND WATER.

Both the north basin and the south basin of the valley have possibilities of further development of the water in the unconsolidated deposits.

The recent success in prospecting for flows in Parowan Valley has revived interest in similar prospecting in Rush Lake Valley, and it is likely that before this paper appears considerable drilling will have been done. Although some irrigation could be accomplished with flowing well water, there is no indication that any extensive tracts could be reclaimed in this manner, because in the areas where flowing wells can be expected the soil is for the most part swampy and alkaline.

If wells of large diameter, several hundred feet deep, were widely scattered over those parts of the valley which have shallow ground water, but which are not swampy or burdened with alkali, and if pumps were applied to these wells, enough water could be recovered to bring hundreds of acres under irrigation. The construction of wells of this type is discussed on pages 59–64. If the water power

of the streams were developed, the pumping could be done at comparatively small cost, but even by the use of gasoline, producer-gas, or a proper type of steam engines pumping for irrigation can probably, with efficient management, be made profitable. Before installing pumping plants the precautions given on pages 49–53 should be observed.

### CULINARY SUPPLIES.

At Cedar City, Hamiltons Fort, and Kanarraville the water from the mountain streams which furnish the irrigation supplies has up to the present time been used for drinking and culinary purposes. At Cedar City the water has been brought into the city through wooden mains; in the other two settlements it is drawn from the open ditches. At Cedar City steps have recently been taken to install a pipe line leading from a mountain spring, and at Kanarraville a similar project is under consideration. At Enoch the culinary supply is derived from springs and wells. The sanitary aspects of water supplies are discussed on pages 53–55.

## ESCALANTE DESERT.

### PHYSIOGRAPHY AND GEOLOGY.

Escalante Desert is an extensive plain surrounded by mountains, most of which are only moderately high. (Pl. II.) The rocks that constitute the mountains differ widely in character, age, and structure, but these differences have so little relation to the occurrence of ground water in the desert that they need not be discussed here. To a large extent the sedimentary formations are covered with volcanic rocks of Tertiary age.

When Lake Bonneville stood near its highest level Escalante Desert was occupied by a large but shallow bay of that lake (fig. 2), as is proved by the ancient shore features, which are distinct although not as impressive as in some localities. The monotonously flat surface of this desert, like that of Sevier Desert and Great Salt Lake Desert, is typical of ancient lake topography.

The desert is underlain by unconsolidated sediments derived from the rock waste of the surrounding mountains. In part these sediments were deposited by the streams; in part they were carried into the ancient lake and were allowed to settle quietly at the bottom of this lake. The lake-formed deposits in the interior of the desert probably consist largely of fine-grained sediments that will not furnish much water, but coarse materials that will yield their water freely are to be expected near the mouths of the principal canyons. The well sections given in succeeding paragraphs throw some light on the character of the unconsolidated beds.

## RAINFALL.

In the following table are given the United States Weather Bureau records of precipitation in this region. At Modena the lightest annual precipitation since 1901, inclusive, was 5.09 inches, and the heaviest 16.62 inches, while the average for eight years is 11.50 inches. By reference to figure 4 it will be seen that the seasonal distribution of the rainfall is here somewhat different from that at the stations in Juab and Millard counties, the spring rainfall being less and the late summer rainfall being greater. Recently dry farming has been undertaken on a large scale near the mouth of Pinto Creek.

*Precipitation (in inches) in Escalante Desert.*

**Modena.**

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1901 | 0.43 | 3.63 | 0.06 | 0.68 | 0.65 | 0.32 | 1.33 | 1.17 | 0.06 | 0.78 | 0.01 | 0.12 | 9.24 |
| 1902 | .33 | .32 | .54 | .13 | .19 | .02 | Tr. | 1.58 | .76 | .04 | .89 | .29 | 5.09 |
| 1903 | .12 | .85 | .74 | .61 | .55 | .13 | .14 | .92 | 1.48 | 1.39 | .00 | .00 | 6.93 |
| 1904 | .20 | 1.01 | .98 | .02 | 1.55 | .11 | .69 | 1.52 | 2.02 | .50 | .00 | .23 | 9.83 |
| 1905 | .86 | 1.79 | 2.09 | 1.05 | .72 | Tr. | .81 | 1.71 | 1.26 | 1.00 | .90 | .20 | 12.39 |
| 1906 | .67 | .47 | 3.22 | 2.91 | 1.31 | .00 | 2.30 | 3.40 | .91 | .34 | 1.40 | 2.13 | 19.06 |
| 1907 | 1.63 | .73 | 2.23 | .51 | 1.71 | .50 | 2.46 | .77 | .09 | 1.71 | .12 | .34 | 12.80 |
| 1908 | 1.62 | 1.47 | 1.10 | .76 | 1.50 | .37 | 2.76 | 2.76 | 1.64 | 1.76 | .03 | .85 | 16.62 |
| Average | .73 | 1.28 | 1.37 | .83 | 1.02 | .18 | 1.31 | 1.73 | 1.03 | .94 | .42 | .52 | 11.50 |

**Near Enterprise.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907 | 3.27 | 1.66 | 3.00 | 0.96 | 1.52 | 0.64 | ...... | ...... | ...... | ...... | ...... | 0.10 | ...... |
| 1908 | 2.53 | 2.56 | 1.09 | 1.56 | 1.37 | .03 | 0.70 | 2.43 | 1.22 | 2.45 | 0.30 | .73 | 16.97 |

**Pinto.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1897 | ...... | 3.05 | 4.11 | 0.78 | 0.52 | 0.05 | 0.90 | 0.89 | 2.17 | 3.76 | 0.40 | 1.16 | ...... |
| 1898 | 1.28 | .68 | 1.33 | .39 | 2.30 | .25 | .07 | .60 | .00 | .00 | .11 | .11 | 7.12 |
| 1899 | .25 | .35 | 2.17 | .40 | .58 | .77 | .05 | 1.06 | .00 | 1.75 | .67 | .49 | 8.54 |
| 1900 | .38 | .27 | .34 | 2.31 | .65 | .25 | .13 | .08 | 1.32 | .77 | 3.16 | .05 | 9.71 |
| 1901 | 1.72 | 2.74 | .23 | .85 | .85 | .45 | .80 | 5.07 | .00 | 1.43 | .39 | .57 | 15.10 |
| 1902 | .61 | .95 | 2.66 | .25 | .19 | Tr. | .01 | 1.71 | .20 | .93 | 3.09 | .70 | 11.30 |
| 1903 | .93 | 1.06 | 1.57 | 1.30 | .80 | .17 | Tr. | 1.74 | 1.37 | 1.75 | .00 | .21 | 10.40 |
| 1904 | .80 | 1.91 | 1.72 | .44 | 1.90 | ...... | 3.25 | 1.97 | .99 | .91 | .00 | .17 | ...... |
| 1905 | .64 | 1.88 | 2.28 | 1.48 | 2.09 | .00 | 1.41 | 1.83 | 4.82 | .77 | 1.67 | .08 | 18.95 |
| 1906 | 2.72 | 1.52 | 6.45 | 2.15 | .93 | .17 | 1.64 | 2.82 | 1.82 | .10 | 2.43 | 2.85 | 25.60 |
| 1907 | 2.63 | 2.00 | 2.92 | ...... | 1.84 | .62 | 2.14 | ...... | ...... | 3.09 | ...... | ...... | ...... |
| 1908 | 1.20 | 2.40 | 1.59 | 2.10 | .95 | .09 | 2.15 | 3.45 | 2.53 | 2.24 | .25 | .90 | 19.85 |

**Lund.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1901 | 0.15 | 1.73 | Tr. | ...... | ...... | ...... | ...... | 0.28 | ...... | ...... | ...... | 0.05 | ...... |
| 1902 | .24 | .05 | .53 | Tr. | Tr. | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1903 | .25 | 1.20 | 1.20 | 0.94 | 0.89 | 0.08 | Tr. | 2.70 | 0.50 | 1.60 | 0.00 | Tr. | 9.36 |

## SOIL.

The native vegetation shows that there are important differences in the character of the soil in different parts of the desert. On the bench lands along the borders sagebrush is found, but on much of the

low flat, where the ground water is near the surface and the soil contains alkali, greasewood and salt brush predominate.

In order to investigate the feasibility of irrigating with ground water in a low area where the water rises nearly or quite to the surface, samples of soil were obtained from two localities in this area, and these samples were analyzed by the United States Bureau of Soils. One set of samples was taken on the flat a short distance south of the station house at Lund, where water was struck at the depth of 6 feet; the other set was taken near Webster's flowing well, a short distance west of the Table Buttes, where water was struck at the depth of 4 feet. In both localities greasewood and salt brush were present, and in both the analyses show a soil that is high in alkali.

*Analyses of soil at Lund, Utah.*

| Depth within which soil was taken. | Soluble solids (alkalies). Per cent of total material. | Predominating salts in order named. |
|---|---|---|
| *Feet.* | | |
| 1 | 2.1 | Sulphates and chlorides. |
| 2 | 2.1 | Do. |
| 3 | 2.5 | Do. |
| 4 | 2.1 | Chlorides and sulphates. |
| 5 | 2.2 | Sulphates and chlorides. |
| 6 | 2.7 | Do. |

*Analyses of soil near Webster's flowing well, Escalante Desert, Utah.*

| Depth within which soil was taken. | Soluble solids (alkalies). Per cent of total material. | Predominating salts, in order named. |
|---|---|---|
| *Feet.* | | |
| 1 | 1.8 | Sulphates and chlorides. |
| 2 | 2.8 | Do. |
| 3 | .8 | Chlorides and bicarbonates. |
| 4 | .4 | Bicarbonates and sulphates. |

## STREAMS.

Because of the general aridity and the low altitude of most of the surrounding mountains, few streams reach Escalante Desert. Aside from Iron Springs Creek, the only permanent streams in the basin rise in the relatively high mountains to the south. (See Pl. II.)

The most westerly of these streams is Shoal Creek, which emerges at Enterprise, in Washington County, and furnishes considerable

water for irrigation in that vicinity. Twelve miles up this stream there is a partly completed reservoir in which the flood waters will be stored, thus adding greatly to the available supply. Formerly the water was used at Hebron, which is farther upstream than Enterprise. Spring Creek is a much smaller stream that rises east of Shoal Creek, but also emerges from the mountains in the vicinity of Enterprise.

Meadow Creek is next east of Spring Creek. Formerly it furnished irrigation water for a small settlement at Hamblin, which is located in a meadow in the mountains, but some years ago heavy spring floods cut a deep gully through this meadow and thus robbed it of most of its water supply. At present the water of the creek is used at the Holtz ranch, which is located at the mouth of the canyon.

Farthest east are Pinto and Little Pinto creeks, which unite and flow out upon the desert at what is called the "Castle," or the "Mouth of Pinto." Much of the water of Pinto Creek is used at a settlement called Pinto, which, like Hebron and Hamblin, is situated in the mountains, but important water rights have also been established below the Castle.

### SPRINGS.

The low mountains west of the railroad contain many small springs which are valuable chiefly as supplies for live stock on the range. Only a few of the best known of these springs are shown in Plate II. Many of them are seeps from the disintegrated igneous rock.

Sulphur Spring is about 1¼ miles west-northwest of Lund and at about the same level. It is situated at the base of a low alluvial slope bordering the western mountains. The small amount of water that it yields is used only as a supply for live stock.

The Desert Springs are situated northwest of Modena and other small springs occur farther up the canyon in which they are found. The locomotive and culinary supplies at Modena come from a number of large dug wells about 4½ miles northwest of the village, the water being conducted to the village, by gravity, through a 6-inch pipe line. At Gold Springs and Stateline, two small mining camps northwest of Modena, the water supplies are derived chiefly from springs.

Iron Springs, which have been described in the section on Rush Lake Valley (p. 145), but whose water drains into Escalante Desert, are the largest springs in the Iron Mountains. Other springs in these mountains and within this drainage basin are Antelope Springs, in sec. 4, T. 35 S., R. 14 W., and Sand Springs, between this point and the Mouth of Pinto. Numerous springs are found in the mountainous area south of the desert.

### FLOWING WELLS.

*Webster's well.*—A flowing well belonging to John Webster is located in the interior of Escalante Desert, along the road leading from the Mouth of Pinto to Lund, a short distance west of Table Buttes, which form a well-known landmark in this region. (Pl. II.) The surrounding country lies low, is flat except for minor irregularities that have been developed by wind erosion, and in wet seasons is partly submerged by accumulating storm waters. The well is 1½ inches in diameter, is reported to be 160 feet deep, and yields several gallons of water per minute by natural flow. The water is good to the taste; it was found to contain only 29 parts per million of chlorine but it gave a slight reaction for normal carbonates.

*Wells at Sulphur Springs and Lund.*—A small flowing well in the vicinity of the Sulphur Springs is said to be 280 feet deep but little reliable data in regard to it could be procured. In his report on the water resources of Beaver County, Lee states that in the 585-foot railroad well at Lund flowing water was struck at 5 horizons,[1] but from the best information available it appears that these flows took place in a pit and that the water never rose higher than within one or two feet of the natural surface.

### NONFLOWING WELLS.

*Railroad wells at Lund.*—The old railroad well at Lund is said to be 4 inches in diameter and several hundred feet deep, but reliable information in regard to it is lacking. Originally the water rose within 1½ feet of the surface, but now it remains at a depth of about 8 feet.

The new well, completed in 1903, was carried to a depth of 585 feet. The casing is 12 inches in diameter at the top, but is reduced to 10, 8, and finally 6 inches. As in the old well, the water at first rose within 1½ or 2 feet of the surface, but has since retreated to a level about 8 feet below the surface. Mr. Lee states that when this well is pumped it yields 100 gallons per minute with a temporary depression of the water surface of less than 20 feet. The following section of the new well, taken from Mr. Lee's report, shows that the sediments underlying Lund are predominantly fine-grained, but that a few beds of gravel and coarse water-bearing sand exist.

---

[1] Lee, W. T., Water resources of Beaver Valley, Utah: Water-Supply Paper U. S. Geol. Survey No. 217, 1908, p. 31.

*Section of the railroad well at Lund, Utah.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Sand | 2 | 2 |
| Clay | 4 | 6 |
| Gravel (small flow) | 6 | 12 |
| Coarse gravel | 4 | 16 |
| Hardpan and clay | 49 | 65 |
| Quicksand | 4 | 69 |
| Blue clay | 80 | 149 |
| Sand | 4 | 153 |
| Red clay | 12 | 165 |
| Blue clay | 159 | 324 |
| Red rock | 6 | 330 |
| Blue clay | 70 | 400 |
| Quicksand | 20 | 420 |
| Green shale rock | 10 | 430 |
| Clay and sand | 10 | 440 |
| Sand (small flow) | 3 | 443 |
| Blue clay | 11 | 454 |
| Clay and sand | 8 | 462 |
| Sand (large flow) | 13 | 475 |
| Clay | 3 | 478 |
| Sand | 6 | 484 |
| Red clay | 2 | 486 |
| Very fine sand | 8 | 494 |
| Red clay | 10 | 504 |
| Dark clay | 4 | 508 |
| Blue clay | 14 | 522 |
| Very fine sand | 3 | 525 |
| Blue clay | 2 | 527 |
| Fine sand (small flow) | 3 | 530 |
| Brown clay | 19 | 549 |
| Sand | 1 | 550 |
| Brown clay | 23 | 573 |
| Coarse sand | 10 | 583 |
| Coarse gravel (large flow) | 2 | 585 |
| Blue clay | | |

The water is only moderately mineralized, as is shown by the following analysis made for the railroad company in January, 1905:

*Analysis of water from the new railroad well at Lund, Utah.*

[Parts per million.[1] Analyst, Herman Harms.]

| | |
|---|---|
| Total solids | 486 |
| Silica ($SiO_2$) | 64 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 4 |
| Calcium carbonate ($CaCO_3$) | 47 |
| Calcium sulphate ($CaSO_4$) | 33 |
| Magnesium carbonate ($MgCO_3$) | 63 |
| Sodium chloride (NaCl) | 116 |
| Magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), volatile and organic matter, and loss | 159 |

*Railroad well at Beryl.*—In the railroad well at Beryl, which is 13 inches in diameter and 208 feet deep, water was found at depths of 23 feet, 180 feet, and 203 feet. The well as finished draws from the 203-foot bed, from which the water rises within 19 feet of the surface. During a pumping test of 24 hours the well is said to have yielded 183 gallons per minute. A 4-foot hole sunk to the depth of 23 feet yielded 20 gallons per minute.

[1] Reported by the chemist in grains per gallon.

*Section of the railroad well at Beryl, Utah.*[1]

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Soil | 8 | 8 |
| Clay and gravel | 8 | 16 |
| Gravel (water-bearing) | 7 | 23 |
| Gravel and clay | 15 | 38 |
| Clay | 80 | 118 |
| Clay and gravel | 57 | 175 |
| Gravel (water-bearing) | 5 | 180 |
| Clay | 20 | 200 |
| Sand (water-bearing) | 3 | 203 |
| Clay | 5 | 208 |

Lee, W. T., Water-Supply Paper U. S. Geol. Survey No. 217, 1908, p. 31.

The water from this well, like that from the Lund well, is used in the boilers of the locomotives. As shown in the following analyses, it contains only moderate amounts of the mineral substances commonly found in ground waters.

*Analyses of water from the railroad well at Beryl, Utah.*

[Parts per million.[1] Analyst, Herman Harms.]

| | Sample from depth of 25 feet [2] | Sample from bottom.[3] |
|---|---|---|
| Total solids | 492 | 344 |
| Silica ($SiO_2$) | 92 | 61 |
| Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$) | 4 | 2 |
| Calcium carbonate ($CaCO_3$) | 72 | 74 |
| Calcium sulphate ($CaSO_4$) | 49 | 41 |
| Magnesium carbonate ($MgCO_3$) | 37 | 42 |
| Sodium chloride ($NaCl$) | 86 | 70 |
| Magnesium sulphate ($MgSO_4$), sodium sulphate ($Na_2SO_4$), volatile, organic, and loss. | 152 | 49 |

[1] Reported by the chemist in grains per gallon.
[2] Sample collected Aug. 27, 1905.
[3] Lee, W. T., Water-Supply Paper U. S. Geol. Survey No. 217, 1908, p. 51.

*State test well near Enterprise.*—A test well was sunk by the State at a point a few rods north of the boundary between Iron and Washington Counties and near the line between Rs. 16 and 17 W. As far as could be ascertained no record was kept and the only information was that furnished from memory by the driller, Mr. Halterman, of Parowan. He states that the materials penetrated by the drill consisted of gravel and other unconsolidated sediments for the first 300 feet, and of red rock from this depth to about 700 feet, where hard rock was struck and the drilling was stopped. He states also that water was found at the depth of 40 feet and at various horizons below this level, and that the water from the unconsolidated sediments rose within about 40 feet of the top of the well, but that the water from the rock remained 90 feet below the surface. It appears that

no tests were made of the quantity or quality of the water and that the well has remained practically unused.

*Well of the New Castle Reclamation Co.*—The New Castle Reclamation Co. has a dug well, 86 feet deep, situated in the NE. ¼ sec. 7, T. 36 S., R. 15 W., several miles northwest of the Mouth of Pinto. In October, 1908, the water in this well stood 81 feet below the surface, was yielded freely, and was considered to be of good quality.

*Section of the New Castle Reclamation Co.'s well.*

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Clay loam | 18 | 18 |
| Gravel | 8 | 26 |
| Clay and sand alternating | 14 | 40 |
| Gravel | 8 | 48 |
| Clay | 27 | 75 |
| Hard clay | 1½ | 76½ |
| Black gravelly sand | 2½ | 79 |
| Dense clay | 1 | 80 |
| Black sand (water which did not rise) | 1 | 81 |
| Dense clay | 1 | 82 |
| Black sand (water which rose to level of first water-bearing bed) | 1 | 83 |
| Clay | 1 | 84 |
| Sand (water which rose to level of first water-bearing bed), entered | 2 | 86 |

*Other wells.*—The well just described is typical of more than a score of wells that have been dug at different points in the desert, chiefly for the purpose of watering sheep or other live stock. Practically all of these wells are less than 100 feet deep because the holes that were dug where the ground-water table is more than this distance below the surface were generally abandoned before the requisite depth was reached. Most of the dug wells yield water of fairly good quality and in ample amounts for stock purposes, but there are exceptions both as to quality and quantity.

## DEPTH TO GROUND WATER.

*Vicinity of Lund.*—The depth to which it is necessary to sink a well in order to reach the ground-water table depends largely on the altitude of the surface. At Lund the water table nearly coincides with the surface, and this condition prevails west of Lund to Sulphur Springs, north, northeast, east, and southeast of Lund for some miles, and south of Lund to beyond Webster's flowing well. With certain interruptions, it also prevails from Webster's flowing well to T. 35 S., R. 16 W., where water is obtained at very shallow depths.

*Between Lund and Modena.*—Along the railroad southwestward from Lund the surface gradually rises, but water can be obtained at moderate depths between Lund and Beryl (see p. 155) and probably between Beryl and a point some distance southwest of Morton, beyond which the railroad has a steeper gradient and the depth to water

is greater. In going from the railroad toward the western mountains the depth to water also increases, and near the mountains it may be impracticable to get wells.

*Southeast of Modena.*—East and southeast of Modena there is an extensive area of fertile land that lies somewhat above the desert flat and is partly encircled by low rocky ridges. Except near the ridges, wells can probably be obtained in this area at reasonable depths, but flows are not to be expected.

*North of Enterprise.*—Water can probably be obtained at moderate depths on a large part of the bench that lies east of the ridge extending northward from Enterprise. On the low ground at the foot of this bench there are some indications that flows could be obtained.

*Vicinity of New Castle.*—An alluvial slope extends along the border of the mountains from Enterprise to the vicinity of New Castle and from New Castle to the north end of the Iron Mountains. This belt is especially wide in the reentrant occupied by the alluvial fan of Pinto Creek. A number of wells already sunk in the region give some indications as to the position of the water table. Thus in the NE. $\frac{1}{4}$ sec. 7, T. 36 S., R. 15 W., ground water was found at the depth of 80 feet; near the middle of the line between T. 36 S. and T. 35 S., in R. 15 W., it was found at about the same depth; and on sec. 31, T. 35 S., R. 15 W., it was found at 25 or 30 feet.

*Eastern part of the desert.*—In the low-lying areas of the eastern part of the desert the water table can be reached by sinking to moderate depths but on the higher benches the distance to water is no doubt great. The Iron Mountains are projected northward in two ranges, one of which extends to Antelope Springs, the other to Iron Springs and beyond. (See Pl. II.) Between these two ranges there is a wide reentrant which occupies a township or more of land and consists of a large alluvial slope in the shape of an amphitheater. In this reentrant plain, especially at the higher levels, the prospects for obtaining water are poor.

## QUALITY OF GROUND WATER.

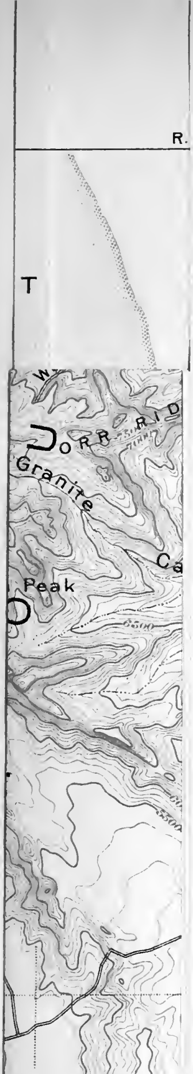
In the railroad wells at Lund and Beryl water of satisfactory quality was found, as is shown by the analyses given on pages 154–155. These analyses and less definite data in regard to other wells indicate that the water in the beds of sand and gravel underlying Escalante Desert is in general not so highly mineralized as to be unfit for culinary use or irrigation. An exception is formed by some of the dug wells in the shallow-water tracts, the water from which, like the soil in the same tracts, may be heavily charged with mineral salts.

## USE OF GROUND WATER.

The ground water of this region is used for locomotive, live-stock, and culinary supplies. Relatively large amounts of fairly good water are required for locomotive supplies, and consequently the most thorough and valuable explorations for ground water in this region have been made by the railroad company. As can be seen from the descriptions of the wells at Lund, Beryl, and Modena, the efforts to secure satisfactory railroad supplies were, on the whole, successful in this region, in which respect Escalante Desert contrasts favorably with the lower part of Sevier Desert and Lower Beaver Valley. Most of the wells in this desert have been dug for the purpose of procuring water for live stock, and many springs have been developed in the western mountains for the same purpose. These watering places have made the range accessible and have thereby added greatly to its value. Recently dry farming has been undertaken and accordingly a new demand for water has been created.

No serious efforts have yet been made to use the ground water for irrigation. Flowing wells are not likely to be of much value for this purpose because they are obtained only in low areas where the soil is impregnated with alkali, and even in these areas the water is under so little pressure that it would be difficult to obtain large enough supplies to be of consequence in irrigation. On land which lies somewhat higher than the alkali desert flats and has better soil considerable irrigation water could in the aggregate be recovered by pumping from moderate depths, but the amount that could be recovered in any one locality is probably not great, and it is doubtful whether even in the more favored tracts pumping for irrigation would be practicable.

# INDEX.

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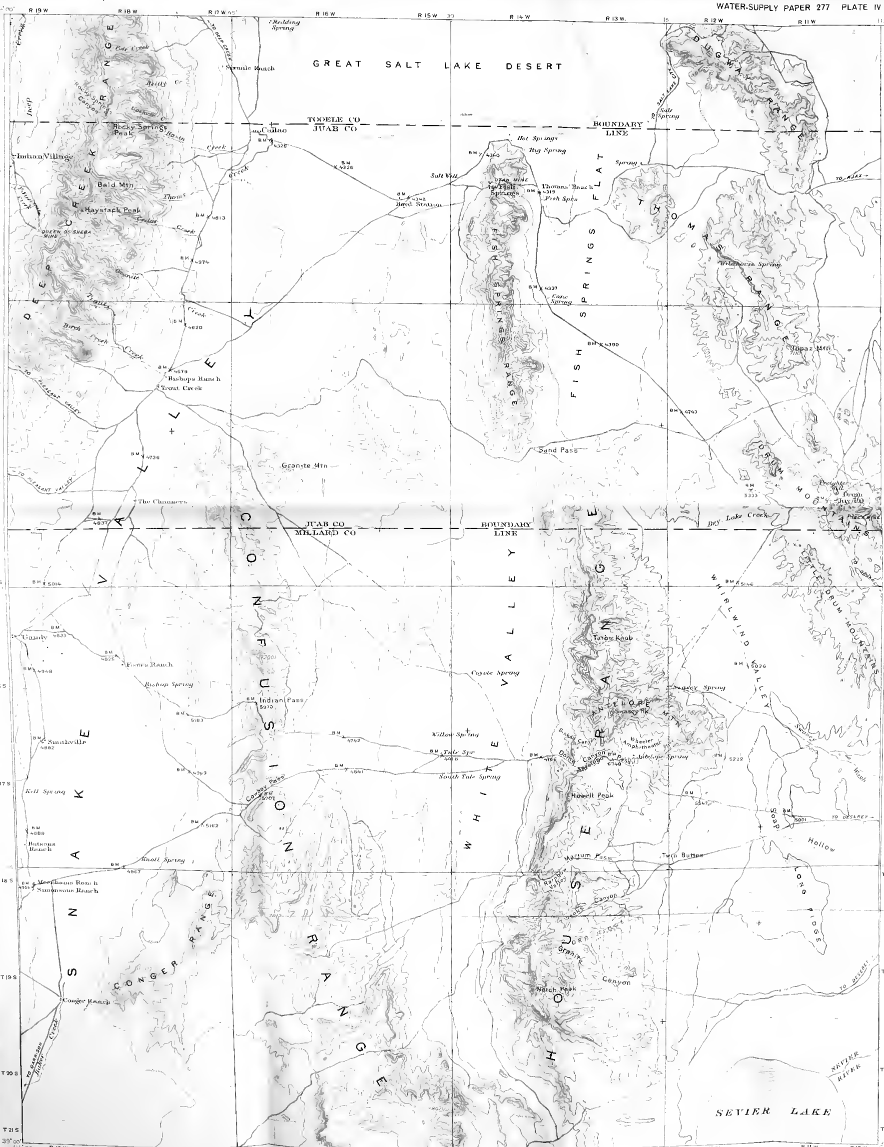


# TOPOGRAPHIC MAP OF FISH SPRINGS QUADRANGLE, UTAH

R B Marshall, Chief Geographer
T G Gerdine, Geographer in charge
Topography by Fred McLaughlin
Control by Coast and Geodetic Survey and T A Green
Surveyed in 1908

Scale $\frac{1}{250000}$

Contour interval 100 feet.
Datum is mean sea level.
1911